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VOLUME 39 (old series Volume 96) FEBRUARY 1948 NUMBER 2

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DEGENERATION AND REGENERATION OF NERVES IN CORNEAL TRANSPLANTATION

An Experimental Study

HUMBERTO ESCAPINI, M.D.
NEW YORK

LITTLE work has been done on the degenerative and regenerative nerve changes that occur in the corneal transplant. It has even been thought that reinnervation of the graft has to do with its transparency or opacification.

In 1915 and 1917, Leoz [1] undertook experimental work to study the regeneration of nerves in the corneal transplant. At that time, the technic of corneal transplantation had not yet reached its present development and high percentage of success. Leoz worked mostly with partial and complete circular keratotomies, and the few homotransplants made were rather large, 9 mm. in diameter, and circular, and the graft was fastened to the host cornea with interrupted sutures. Only 1 of his rabbits with homotransplants had a partially clear graft; this rabbit was killed eight months after the operation, and a study of its nerves was made. He stated that sixty days after the operation he obtained an anergic oculopalpebral reflex on stimulation of the graft and that histologic preparations of graft showed good regeneration of its nerves in the eighth month.

In 1932 Castroviejo,[2] discussing the recovery of sensitivity in the corneal transplant, stated that in transparent grafts in rabbits he obtained an anergic oculopalpebral reflex three months after the operation.

The investigation was sponsored by the Resident's Fund, Institute of Ophthalmology of the Presbyterian Hospital.

Submitted in October 1946 in partial fulfilment of the requirements for the degree of Doctor of Medical Sciences of Columbia University College of Physicians and Surgeons. The first part of this thesis, dealing with the normal structure of peripheral nerves and their degenerative and regenerative phenomena, has been omitted for the sake of brevity. Dr. Ramón Castroviejo gave invaluable assistance in planning and carrying out this work.

1. Leoz, O.: Algunos estudios y ensayos sobre queratoplastias, Arch. de oftal. hispano-am. **15**:225-233, 1915; Contribucion de mis estudios experimentales sobre queratoplastia, ibid. **17**:615-629, 1917.

2. Castroviejo, R.: Keratoplasty, Am. J. Ophth. **15**:905-916, 1932.

PRESENT INVESTIGATION

The present study was carried out on albino rabbits weighing 6 pounds (2.7 Kg.). Rabbits are convenient for use in the laboratory, and one may obtain all the material necessary, not only for demonstration of the clearness or opaqueness of the graft but for timing the age of the transplants according to the demands of the work.

With the present development of corneal transplantation, the operation in the human being is successful in a high percentage of selected cases.[2] This percentage of successes is somewhat lower in experimental work on rabbits, owing to the absence of aseptic conditions and the impossibility of keeping the animals from rubbing the grafted eye with the foot or against the cage.

The rabbits used in this work were anesthetized with "pernoston sodium" (sodium 5-*sec.* butyl-5-β-bromallylbarbiturate). Two cubic centimeters of a 10 per cent solution of the drug was injected into the peritoneum, and good narcosis was obtained in twenty to thirty minutes. The technic of Castroviejo [3] for the square partial penetrating keratoplasty was followed in all cases.

The rabbits so operated on were kept alive for periods of two weeks to nine months. During this time they were subjected to repeated tests to determine the recovery of corneal sensitivity. Attention was given to the least attempt to blink after stimulation of the cornea.

It is known that man is most suited to the study of the processes of sensory recovery after nerve lesions because he can give verbal information as to the quality of sensation which is felt.

Gutmann and Guttmann,[4] studying in rabbits the factors which affect recovery of sensory function after nerve lesions, found that the onset of recovery is delayed and its progress slower after section of a nerve and that the degree of recovery is definitely less than after crushing. They observed an average rate of recovery of 1.98 mm. a day after crushing the peroneal nerve and 1.57 mm. a day after severing and suturing.

To test corneal sensitivity, a small cotton brush was used. A small piece of cotton was rolled between the index finger and the thumb, leaving its ends fluffy so as to make a small brush about 0.5 mm. in diameter. The cornea was gently touched with the brush until a slight flattening of the tip of cotton was obtained; pressure on the cornea was avoided in order to eliminate misleading reactions. The testing should be done gently to avoid abrasions of the corneal epithelium and the possibility of infection, development of ulcers and opacification of the graft, such as occurred in 1 of my rabbits with a clear graft.

The cornea was divided into three zones for the purpose of exploring its sensitivity: (*a*) an area of 2 mm. of the host cornea surrounding the graft, (*b*) the periphery of the graft and (*c*) the center of the graft.

The testing was begun on the second week after the operation and was repeated weekly for several months—in some of the rabbits for eight or nine months. All the rabbits were tested regardless of whether the transplant was clear or opaque.

It was found that the corneal graft was insensitive to the stimulus during the first few weeks after the operation, so that in some cases

3. Castroviejo, R.: Present Status of Keratoplasty, Arch. Ophth. **22**:114-126 (July) 1939; Keratoplasty, Am. J. Ophth. **24**:139-155, 1941.

4. Gutmann, E., and Guttmann, L.: Factors Affecting Recovery of Sensory Functions After Nerve Lesions, J. Neurol. & Psychiat. **5**:117-129, 1942.

the corneal suture was removed without tetracaine hydrochloride being instilled previously and without the slightest reflex being elicited. Moreover, this lack of sensitivity was also found in the 2 mm. zone of host cornea surrounding the graft.

This status of sensitivity in the graft and the host cornea surrounding it has its explanation in the degenerative changes occurring in the nerves of the graft and the surrounding cornea, as shown in histologic preparations. There, alterations were in accordance with the analgesia following severance of sensory nerves, affecting not only the areas corresponding to the distal stump but a small area corresponding to the peripheral end of the central stump as well.

Recovery of sensory function in the clear graft became noticeable about the forty-fifth day after operation. In fact, on stimulation of the graft, a dull reaction was first induced in the form of a rather sluggish palpebral reflex. This corneopalpebral reaction became more active about the seventieth day, its final degree appearing to be less than normal; furthermore, it began to manifest itself at the periphery of the graft and remained more active there.

Recovery of sensitivity in the graft is a clear expression of nerve regeneration taking place in the graft. As a matter of fact, histologic sections showed the presence of new nerve fibers in the graft at the time a response to stimuli was obtained. This functional recovery gives no indication of the rate of reinnervation, since the latter takes place before any functional manifestation can be elicited. Maturation of the new axons occurs before return of function.

The physiologic tests performed show that the return of the corneal sensitivity takes place slowly. Considering the short distance involved in these experiments, the rate of recovery is low as compared with the rate of sensory recovery after section of the peroneal nerve.[4] In fact, the greatest distance through which reinnervation has to take place is 5 mm.; assuming that recovery starts as soon as the nerves are cut and that it proceeds smoothly, it may be estimated that for recovery of sensory function after keratoplasty nine days is required for each millimeter of reinnervation.

After the rabbits were killed, the whole cornea, or the square piece of the graft only, was fixed for two weeks in a neutral solution of formaldehyde U.S.P. (1:5). Frozen sections, 10 to 15 microns thick, were cut and impregnated with silver nitrate, according to the method of Gross-Schultze.[5] With this technic, the axis-cylinders stain black. With carmine used for counterstaining, the nerves stand out better on a pinkish background.

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5. Mallory, F. B.: Pathological Technique, Philadelphia, W. B. Saunders Company, 1938.

STRUCTURE OF THE NORMAL NERVES OF THE CORNEA

The nerves of the cornea proceed from the fifth cranial, or trigeminal, nerve; the ophthalmic branch of this nerve divides into three branches to form the lacrimal, the frontal, and the nasociliary nerve the last one giving off the long ciliary nerves and the long, or sensory, root of the ciliary ganglion, from which the short ciliary nerves spring. Long and short ciliary nerves participate in the nerve supply of the cornea.[6] Nothing is to be added to the classic studies on the corneal nerves made by Dogiel,[7] Attias [8] and Hoyer.[9]

It is established that from sixty to eighty nerve trunks penetrate the cornea at the limbus, at the junction of the posterior third and the anterior two thirds of its stroma.[10] In addition to these large trunks, the superficial layers of the cornea at the periphery are innervated by the conjunctival, episcleral and scleral nerves in a triangular area.

When the nerves enter the cornea, they are rather thick trunks formed by a variable number of nerve fibers, which are either dissociated and clearly seen or packed together in an even dark stem (fig. 1).

The corneal nerves are oriented toward the center and the surface of the cornea. Their diameter decreases gradually as they approach the corneal epithelium. Soon after they have penetrated the corneal stroma, they give off a branch at an acute angle; from time to time new branches arise from the same trunk. In time the branches give off secondary and tertiary branches by successive divisions.

Besides the thick nerves, the corneal stroma has thin nerves formed of a single nerve fiber; they pursue a straighter course than the thick ones and have the same orientation. Martinez,[11] in one of the most recent articles on the nerves of the human cornea, stated that in the stroma the nerves follow the lacunar system of the cornea, lying on the syncytium formed by the fixed cells of the stroma. All the stromal nerves, through successive branching, crossing, lending fibers to each other or real anastomosis, form a wide plexus, the fundamental plexus. Its constituent elements become increasingly thinner as they approach the epithelium. Once they have reached the subepithelial region, they form, by intercrossing, the subepithelial plexus, from which the epithelial nerves originate.

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6. Goldnamer, W. W.: The Anatomy of the Human Eye and Orbit, Chicago, The Professional Press, Inc., 1923.

7. Dogiel: Die Nerven der Cornea des Menschen, Anat. Anz., **5**:483-494, 1890.

8. Attias, G.: Die Nerven der Hornhaut des Menschen, Arch. f. Ophth. **83**:207-314, 1912.

9. Hoyer: Ueber der Nerven der Hornhaut, Arch. f. mikr. Anat. **9**:220, 1873.

10. Salzman, M.: The Anatomy and Histology of the Human Eyeball, Chicago, University of Chicago Press, 1912.

11. Martinez, R.: Etude sur l'innervation de la cornée humaine, Trab. d. Inst. Cajal d. invest. biol. **32**:75-109, 1940.

The epithelial nerves consist each of a single nerve fiber, which has a rather straight course and becomes thinner as it nears the surface of the cornea. The nerves pass among the epithelial cells, at times penetrating their cytoplasm and coming in contact with their nuclei. They end in sharp points or in fine round or pearlike formations.[7] Martinez [11] was not able to find these formations. Our observations agree with those of this author.

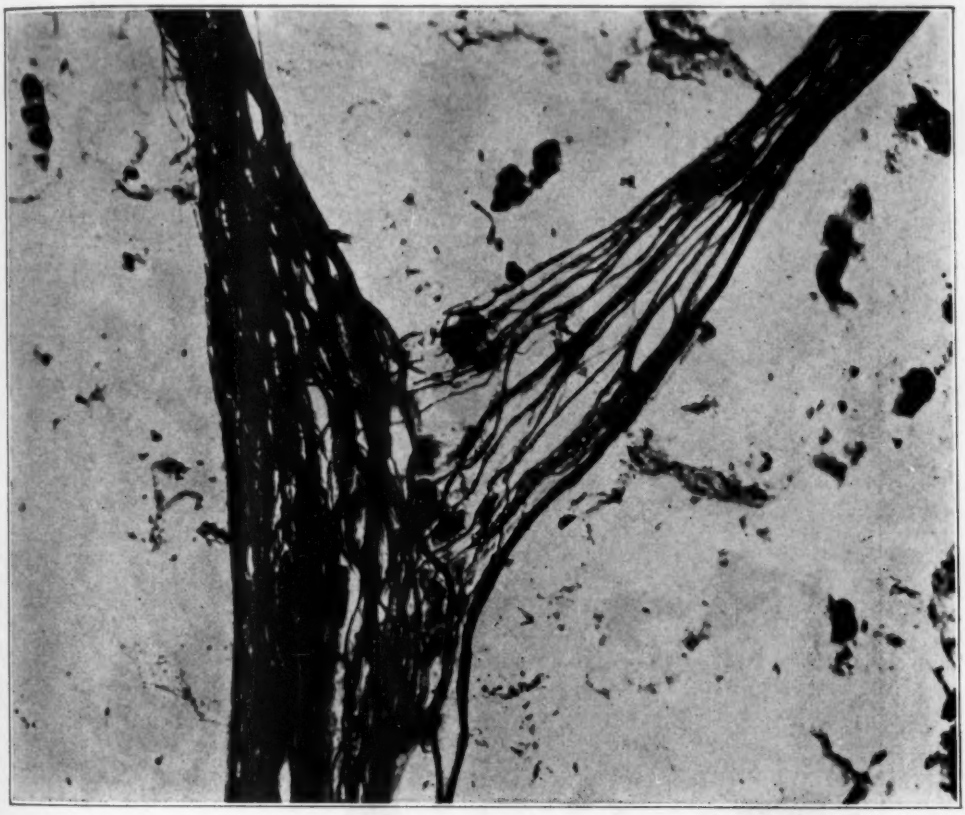

Fig. 1.—Normal cornea. Corneal nerve with simple plain division. × 600.

As has previously been stated, the nerve trunks begin to give off branches soon after they have penetrated the cornea, usually after they have lost their myelin sheath. In general, they divide into two branches of different size (fig. 1), more rarely into three branches (fig. 2). The branching is at a more or less acute angle; however, from some single-fibered nerves a fine branch is seen to spring in T fashion. When a nerve gives off a branch, one of two patterns may be followed: Either the nerve fibers clearly separate into two bundles to form the new branch

Fig. 2.—Normal cornea. *1*, corneal nerve with irregular plate at a three branch division; 2, two branch division with triangular plate. × 630.

or some of the nerve fibers divide again at the same time; in the last event, the new nerve fibers are always thinner than the original ones. In most cases there is a dark-stained plate at the bifurcation of the nerve; 66 per cent of nerves show a plate, which frequently is triangular (fig. 2), or more rarely round (fig. 3) or elliptic (fig. 4).

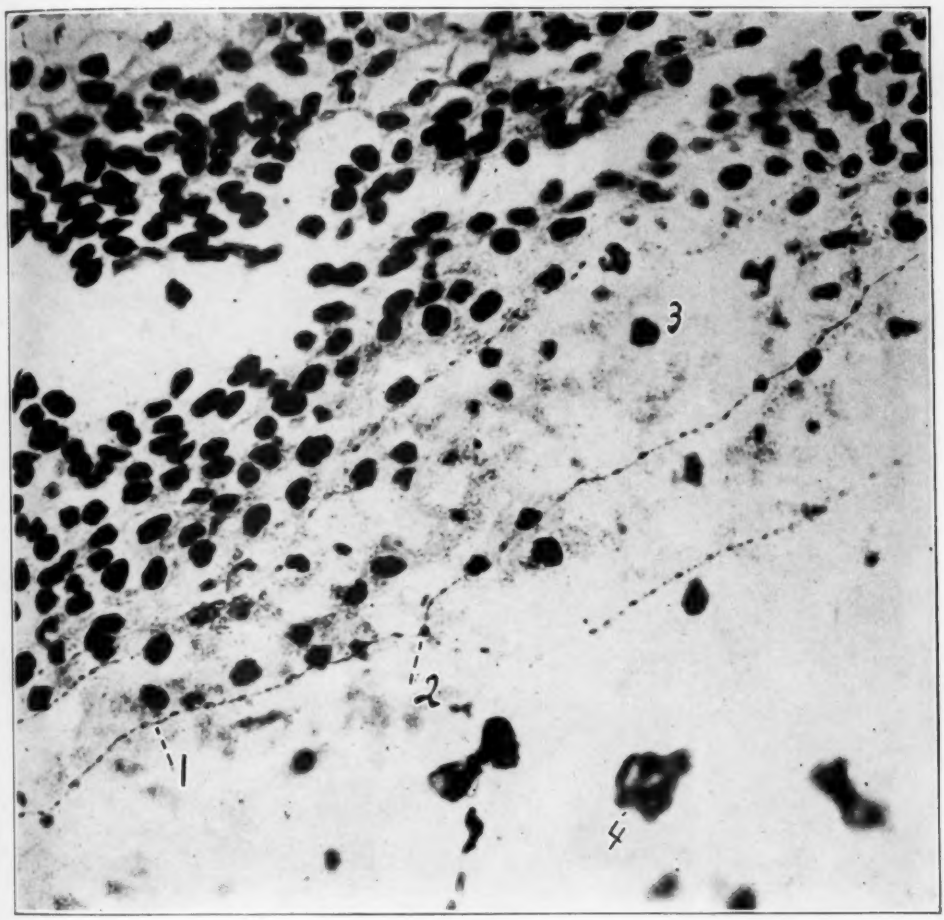

Fig. 3.—Normal cornea. *1*, epithelial nerve in the cornea; *2*, branching nerve with round plate; *3*, epithelial nuclei; *4*, corneal corpuscle. × 730.

Occasionally, it is observed that when a nerve is broken, bridging fibers pass from one branch to the other; they do not come from the original trunk but arise from other nerve trunks and follow a retrograde course in the branch (fig. 5).

When the nerves penetrate the cornea, each nerve fiber is formed of three elements: (*a*) the sheath of Schwann, (*b*) the myelin sheath

and the (*c*) axis-cylinder.[12] The majority of the fibers lose their myelin sheath about 0.5 mm. from the limbus, before their first branching[13]; some of them, however, keep their myelin sheath for a longer distance. The axis-cylinders appear as black filaments with a uniform diameter; at the bifurcations, using the highest magnification, it is possible to see small, rather elliptic swellings. The diameter of the axis-cylinders is

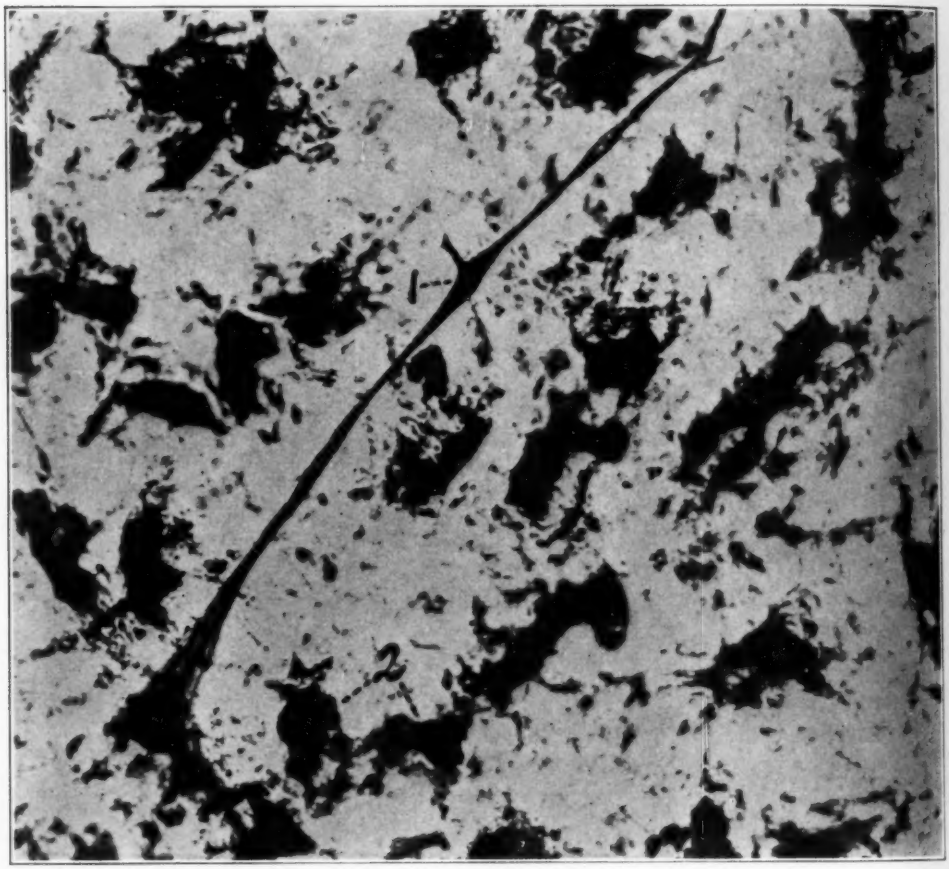

Fig. 4.—Normal cornea. *1*, corneal nerve with oval plate at a two branch division; *2*, corneal corpuscle. × 600.

not always the same; at the periphery of the cornea they are thicker than at the center; furthermore, in the same nerve some axis-cylinders are thicker than others, in places having a ratio of 1 : 5 or 1 : 10.

12. Bailliart, P., and others: Traité d'ophthalmologie, Paris, Masson & Cie, 1939.

13. Wolff, E.: The Anatomy of the Eye and Orbit, Philadelphia, The Blakiston Company, 1940.

Surrounding the axis-cylinders there is in the stromal nerves a clear halo with well defined edges, more easily distinguished in the single-fibered nerves (fig. 6). This halo was described as a plasmatic sheath by Nageotte [14] and Martinez [11]; the former stated that it was defined by a sheath similar to the sheath of Schwann.

Along the axis-cylinders, elongated nuclei are seen lying in the clear halo (fig. 7); they have a clear nuclear membrane and round or taper-

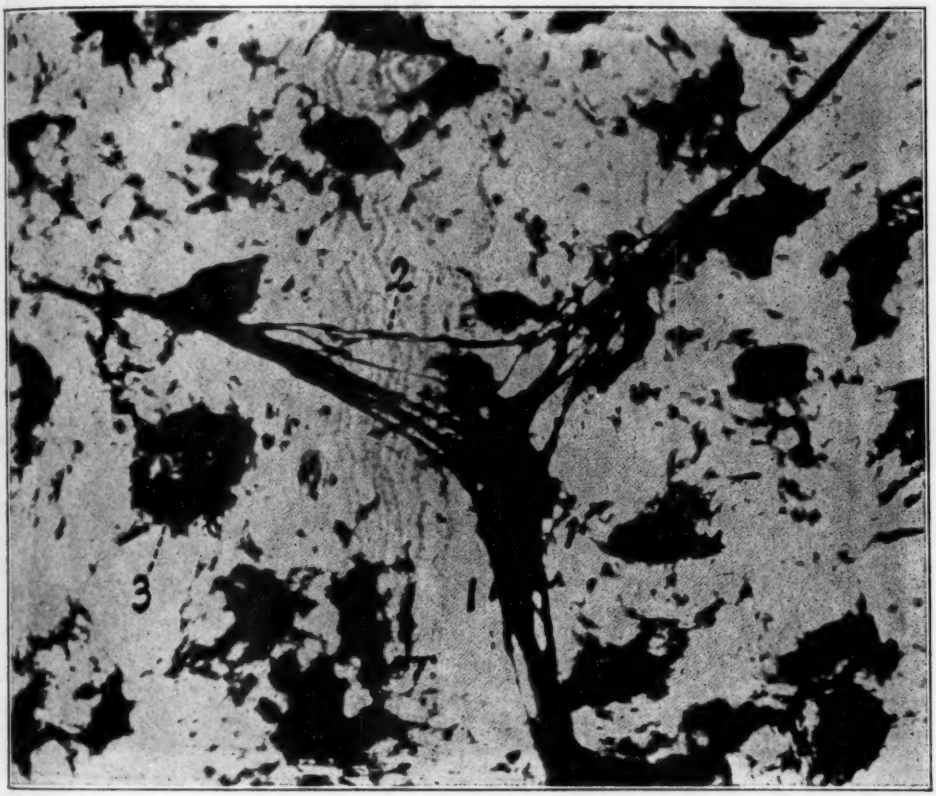

Fig. 5.—Normal cornea. *1*, large nerve with a two branch division; *2*, bridging nerve fiber; *3*, corneal corpuscle. × 600.

ing ends and contain a nucleolus and several round granules of chromatin. It is clear that the morphologic character of these nuclei is much like that of the Schwann nuclei, and unlike those of the fixed cells of the

14. Nageotte, J.: Sheath of the Peripheral Nerves: Nerve Degeneration and Regeneration, in Penfield, W.: Cytology and Cellular Pathology of the Nervous System, New York, Paul B. Hoeber, Inc., 1932. (*b*) Nageotte, J., and Guyon, L.: Le syncytium de Schwann dans les plexus de la cornée, ses connexions avec l'epithelium, Compt. rend. Assoc. d. Anat., 1926.

stroma, which Boeke [15] considered them to be. In fact, this author also held that there was continuity between the nerves and the corneal elements.

It is evident that the halo occupies the space left by the disappearance of the myelin sheath and that it contains the Schwann nuclei. It forms a tubelike structure, the center of which is occupied by the axis-cylinder, and its contour is defined by a Schwann sheath.

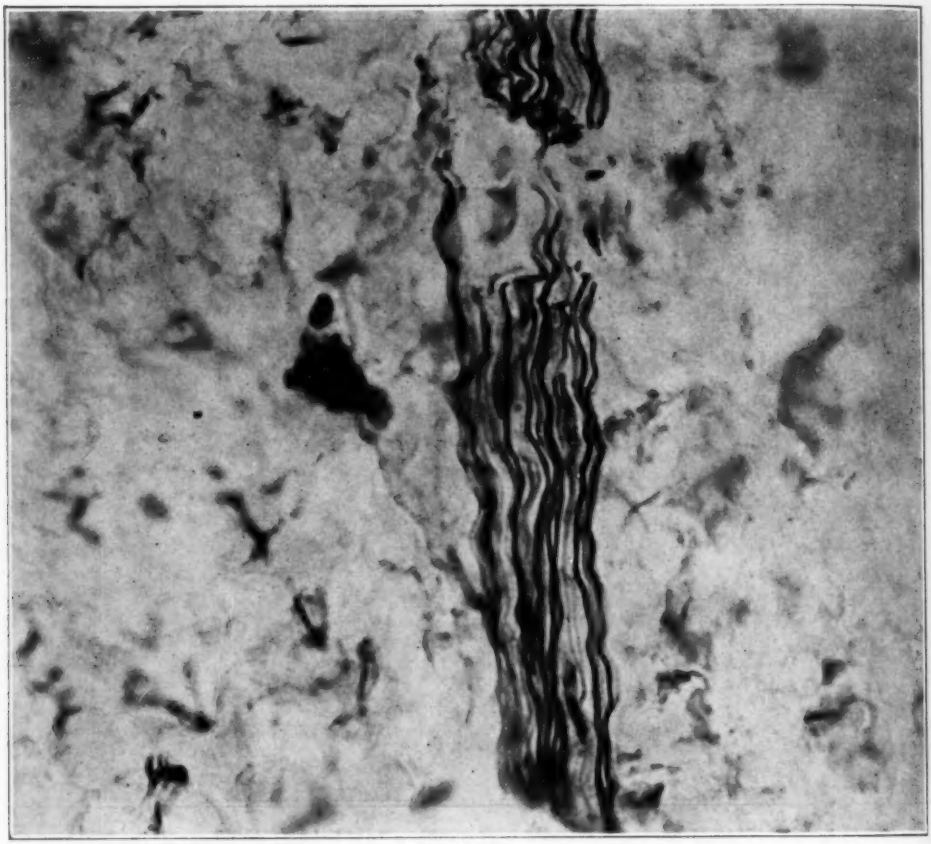

Fig. 6.—Normal cornea. Nerve with dissociated fibers and plasmatic sheath. × 630.

Characteristic features distinguish the epithelial nerves from the stromal nerves. The epithelial nerves are formed of single axis-cylinders, a striking feature of which is the presence of small, round beads along their course, giving them a moniliform appearance (fig. 3). On the other hand, the axis-cylinders are naked, since no sheathing

15. Boeke, J.: Die Beziehungen der Nervenfasern zu den Bindegewebselementen und Tastzellen, Ztschr. f. mikr. anat. Forsch. **4**:448-509, 1926.

is detected around them. In the epithelium, naked axis-cylinders come in contact with the epithelial cells.

DEGENERATION OF CORNEAL NERVES IN VITRO

Degeneration of the nerves is a vital process; to study it in vitro, one should keep the nerves in the best living conditions. According to Ramón y Cajal,[16] degeneration is a manifestation of life—once life

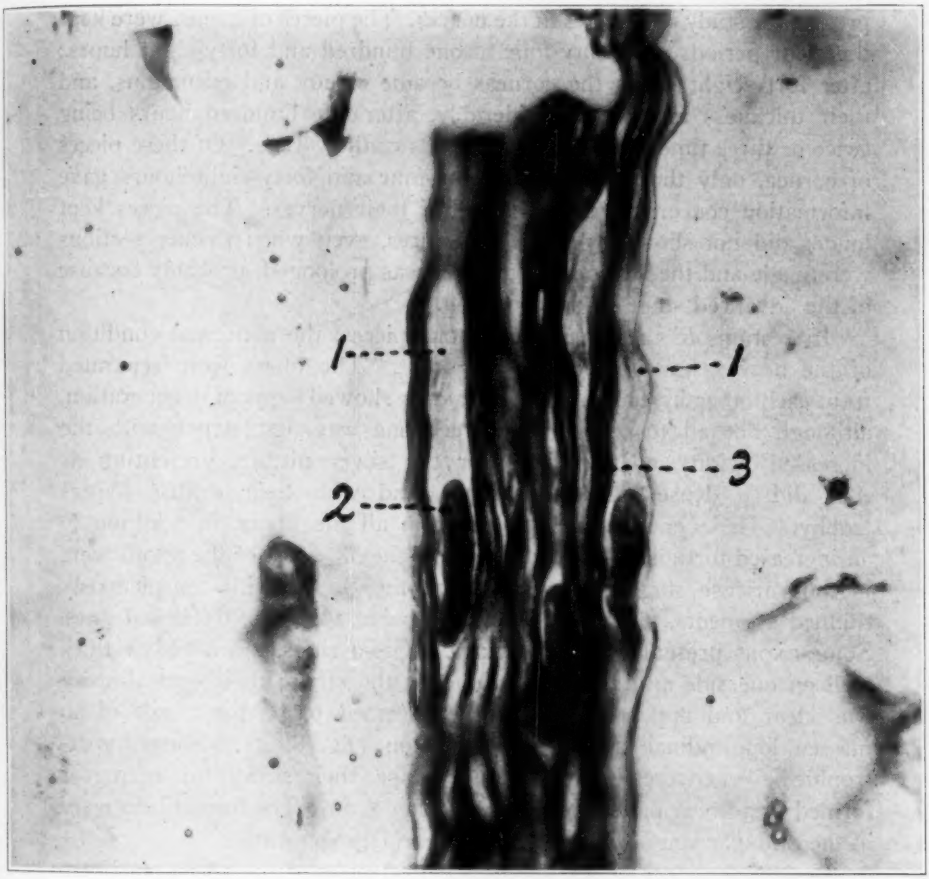

Fig. 7.—Normal cornea. Nerve with (*1*) plasmatic sheath; (*2*) Schwann nucleus; (*3*) nerve fiber. × 1,260.

activities are paralyzed or putrefaction starts, the process stops. Ingebrigtsen,[17] by culturing pieces of brain of chick embryos, was able

16. Ramón y Cajal, S.: Degeneration and Regeneration of the Nervous System, London, Oxford University Press, 1928.

17. Ingebrigtsen, R.: Study of the Degeneration and Regeneration of Axis Cylinders in Vitro, J. Exper. Med. **17**:182-191, 1913.

to study in vitro not only the outgrowth of new axis-cylinders but their spontaneous degeneration after the fifth day or their degeneration after their severance.

To study the degenerative nerve changes that might occur in the cornea in vitro, rabbit corneas were used. They were kept in two ways: (*a*) in the moist chamber in Ringer's solution at a temperature of 37 C., and (*b*) immersed in Ringer's solution at a temperature of 2 C.

In the moist chamber at 37 C. the best living conditions were present for study of changes in the nerves. The pieces of cornea were kept there for periods of twenty-four to one hundred and forty-eight hours; after forty-eight hours the corneas became cloudy and edematous, and their thickness increased considerably, after one hundred hours being twice or three times the normal thickness of the cornea. Of these pieces of cornea, only those kept for twenty-four and forty-eight hours gave information concerning the behavior of their nerves. The pieces kept longer did not show any nerve structures, even when thicker sections were made and the silver impregnation was prolonged, probably because of the advanced stage of degeneration.

In sections of the twenty-four hour pieces, the abnormal condition of the nerves was immediately apparent. The fibers were separated from each other by edema. All the axons showed signs of degeneration, although not all to the same degree; one was first struck with the increased avidity of the fibers for the silver nitrate, presenting as they did, a dense, dark appearance, and with their diffuse hypertrophy. These changes were present in all the fibers, in addition to an increased tortuosity in the majority of them. Most of the axons were in the varicose stage of degeneration (fig. 8, *1*), with conspicuously thinned segments, alternating with somewhat tortuous, thickened ones. Some axons presented annular rings. These rings had a rather thick wall on one side and a very thin one on the other; their central space was clear and appeared empty; they seemed to be the result of an uneven longitudinal splitting of the axon (fig. 8, *2*). Some hypertrophied fibers were in a pregranular stage, their surface appearing as formed by a linear packing of granules (fig. 8, *3*). The finest fibers were in the granular stage but still kept a linear arrangement.

Besides the more or less uniform hypertrophy of the axons, fusiform swellings were seen along their courses. These axons had at irregular intervals pronounced strictures, which led one to consider them to be in a prefragmentation phase of degeneration, true fragmentation being present in occasional axons. A still more advanced stage of degeneration was present in some axons, which showed vacuolation; small, round, clear vacuoles were alined along the axon.

All these changes in the axons set in and progressed with no appreciable reaction on the part of the nerve sheath and its nucleus; the

latter structures seemed to be indifferent to the regressive changes occurring in the axon.

It could be inferred from the previous description that after twenty-four hours of incubation all the axons showed unequivocal signs of

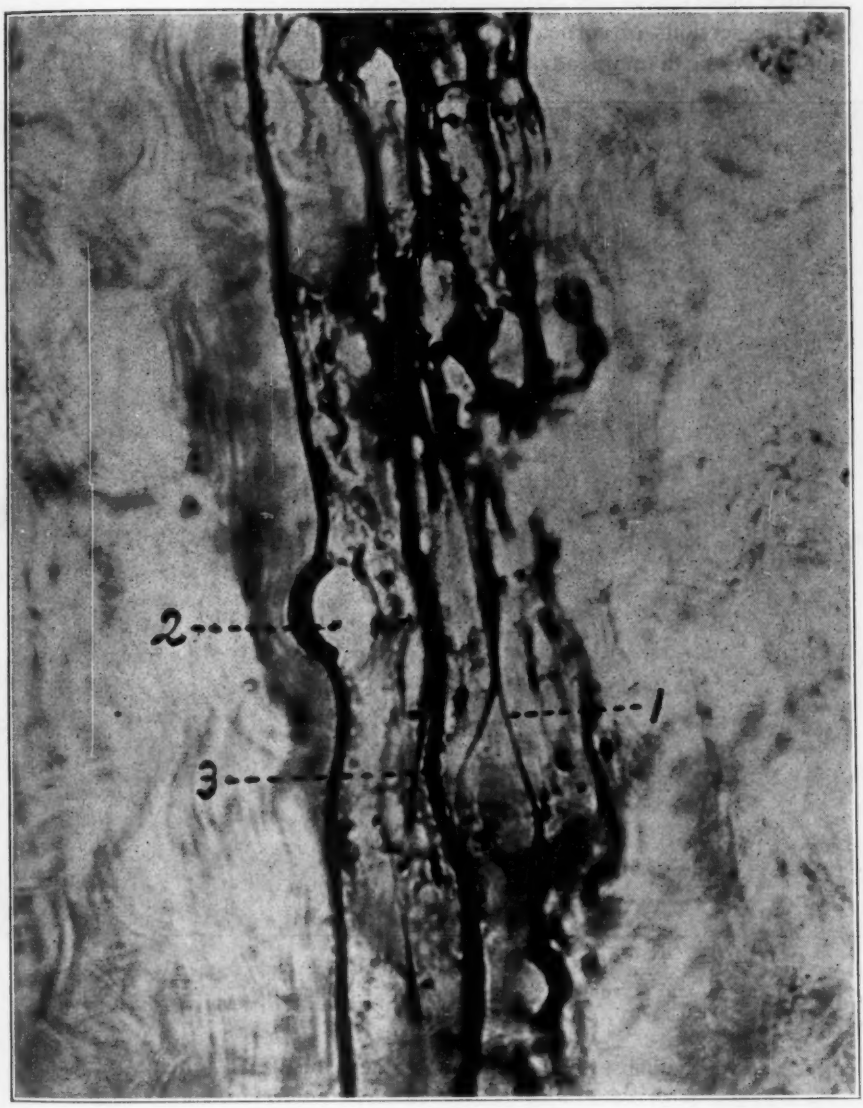

Fig. 8.—Flat section of a cornea kept twenty-four hours in the moist warm chamber. *1*, varicose stage of degeneration; *2*, annular rings; *3*, pregranular stage. × 1,260.

degeneration, ranging from simple hypertrophy to vacuolation and rare fragmentation, most of the axons being in a varicose stage. It is note-

worthy that not all the fibers were equally liable to degeneration; the thinner ones showed the more advanced degenerative changes. This allowed us to see in a single nerve trunk fibers in various stages of degeneration. In no case were the least manifestations of regressive change observed in the Schwann elements of the axons.

The sections of cornea kept for forty-eight hours at 37 C. showed the nerves in a more advanced stage of degeneration (fig. 9). Most

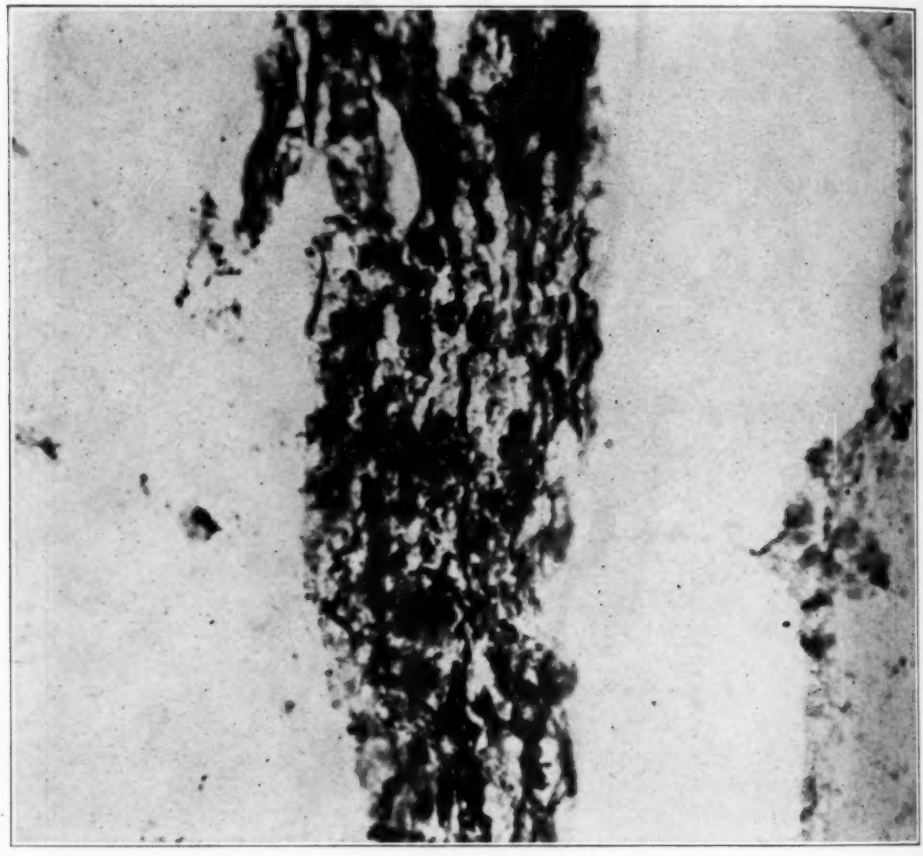

Fig. 9.—Flat section of a cornea kept forty-eight hours at 37 C., showing fragmentation and granulation of the axons. Notice the presence of clublike fragments. × 630.

of the axons had lost their continuity; they were in fragments of various lengths with pronounced hypertrophy, which in some fragments was greater at one end, giving a clublike appearance.

The fragments were flexuous; some of them being coiled and arranged along the nerve tube or across it; most of them were in a granular stage; some still kept their continuity. Some sections showed

splitting and vacuolation of the broken axons. Besides these changes, the whole picture of the nerve was obscured by a diffuse granulation. The process of degeneration had gone farther in some nerves; most of their nerve fibers had disappeared completely, and the remnants were in the form of granulated axonic debris, scattered in the path of the nerve.

The corneas kept at a temperature of 2 C. were not in the best condition to study manifestations of living tissues. However, degenerative changes of a rather low grade took place. In fact, they started later and proceeded more slowly than in corneas incubated at 37 C. After the sections had been ten days at 2 C. the changes in the nerves corresponded to those observed in corneas kept twenty-four hours at 37 C. Most of the fibers showed, in addition to diffuse hypertrophy and increased avidity for the silver nitrate, a varicose stage of degeneration; some of them were in the granular stage, a linear arrangement being preserved. Fusiform swellings were seen, and occasional fibers presented vacuoles and fragmentation.

DEGENERATIVE NERVE CHANGES ASSOCIATED WITH CORNEAL TRANSPLANTATION

When a corneal graft is cut, the corneal nerves are severed, and the nerves in the graft represent their distal stumps; these undergo wallerian degeneration, like that in the distal stump of any severed peripheral nerve. These secondary degenerative changes occur as the result of isolation of the nerves of the graft from the trophic stimulus that emanates continuously from the nerve cells of the corresponding centers. An important fact is that degenerative changes are also observed in the nerves of the host cornea in an area of about 2 mm. around the graft. These changes correspond to the traumatic degenerative changes that occur in the peripheral end of the central stump of any severed nerve, as the result of the direct action of the trauma.

The condition of the nerves in the graft and in the host cornea surrounding it furnishes the explanation of the anesthesia found in these areas. The earliest graft studied was that of a rabbit with a clear transplant which died as the result of diarrhea seven days after the operation. While the eye was being handled in the laboratory, the graft became detached, and only the graft was carried through the laboratory procedure.

The changes in the axis-cylinders were slight and limited to rare swellings and a manifest increased avidity for the silver nitrate. There were no interruptions in the continuity of the axons; however, some axons were in a pregranular stage. The plasmatic sheath surrounding the axons stood out more clearly and at places showed a fine, dark granulation.

The degeneration proceeded rather slowly, so that on the twelfth day the number of swellings had increased. On the other hand, the changes had progressed more rapidly in the host cornea surrounding the graft. In the twelve day transplant, the host nerves in an area 2 mm. in width had gone farther than those in the graft. The axons were extremely hypertrophied and of irregular caliber, with interruptions in their continuity and pronounced avidity for silver nitrate.

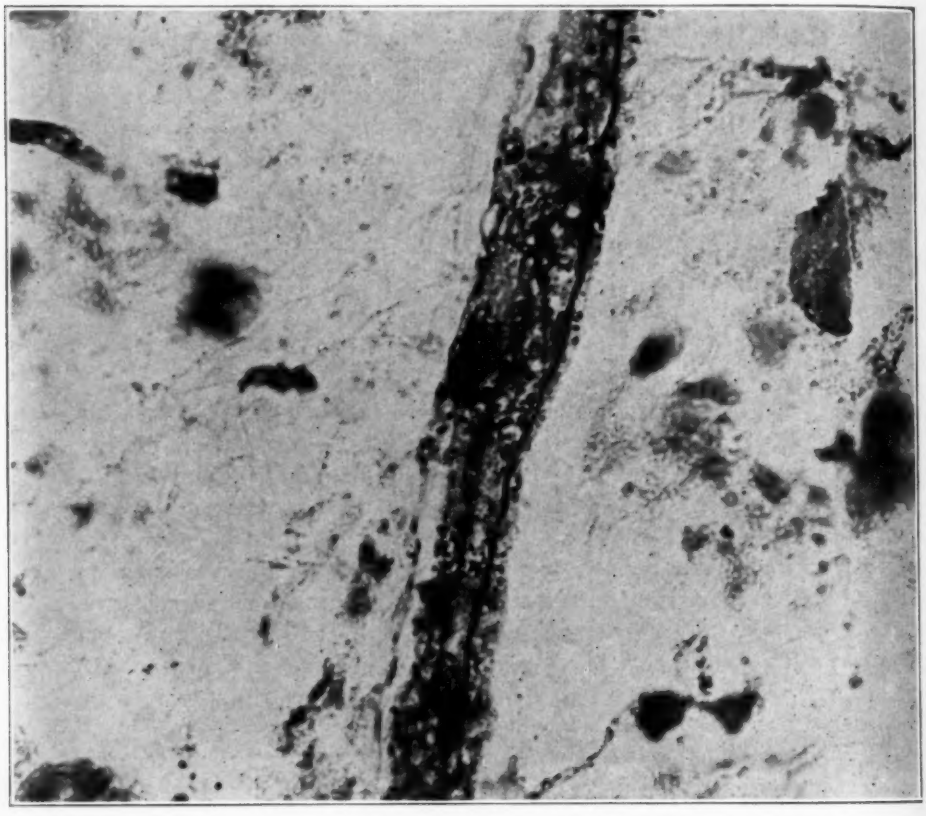

Fig. 10.—Flat section of a clear graft thirty days old, showing granulation and vacuolation of the axis-cylinders with a well preserved one. × 1,100.

The Schwann nuclei stained densely, and there was no indication of their proliferation.

In the thirty day graft, the degenerative changes were so advanced that, except for rare resistant axons, the majority were no longer recognizable (fig. 10). The dominant feature here was the almost complete fragmentation and granulation of the majority of the axons. Many small, round, darkly stained granules were strewn in the path of the nerves; in places, they had a linear arrangement, as though the granu-

lation had just taken place. The most prominent detail was the presence of small, round, clear vacuoles; most of them were scattered irregularly within the nerve tubes, and some showed a linear arrangement.

In addition to these changes in the axons, the plasmatic sheath stood out clearly. The Schwann nuclei had undergone appreciable hypertrophy, with increase in the number of chromatin granules.

As was true of the degenerative changes in nerves observed in vitro, not all the nerve fibers showed them in the same stage. This enabled

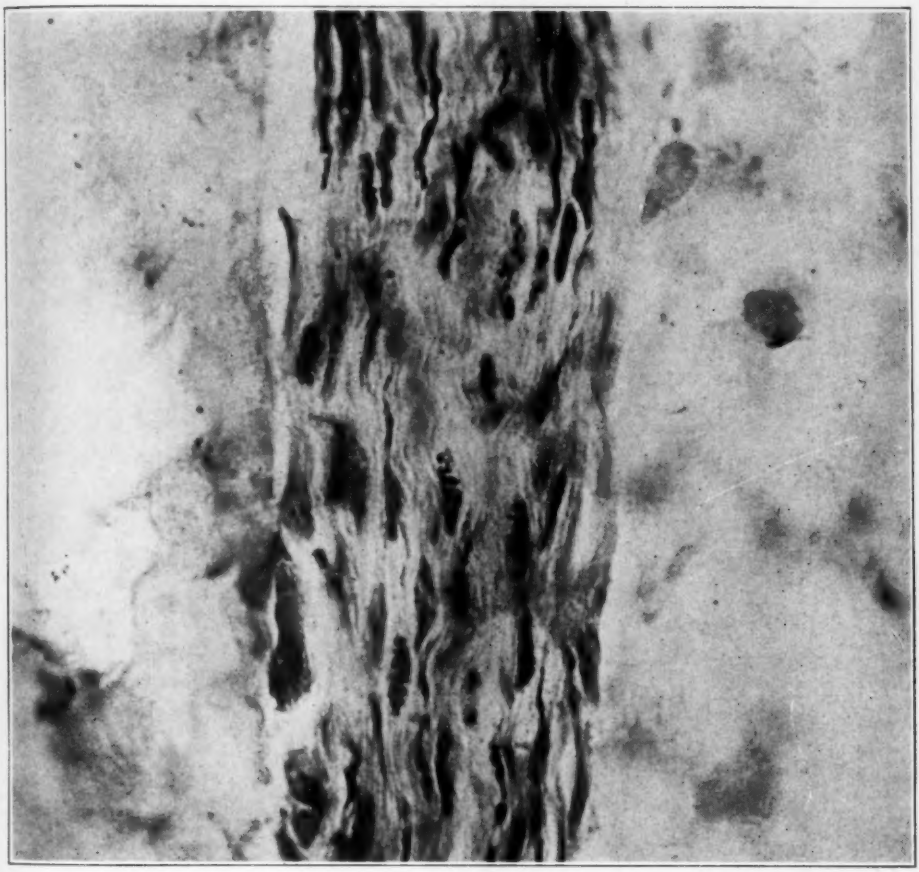

Fig. 11.—Flat section of a translucent graft of one hundred and fifty-eight days. The axis-cylinders are reduced to small granular pieces. × 1,100.

one to see, in addition to the advanced stages of degeneration, axons that had been broken down only into swollen, irregular pieces. There were rare axons which maintained their continuity but showed unequivocal signs of degeneration, such as irregularities in diameter with diffuse hypertrophy, localized fusiform swellings, increased tortuosity and greater avidity for the impregnating material (fig. 10).

The disintegration of the nerves increased gradually until complete granulation of the nerve fragments took place. Figure 11 shows a nerve in which the axons are reduced to small, granular pieces, most of them having disappeared.

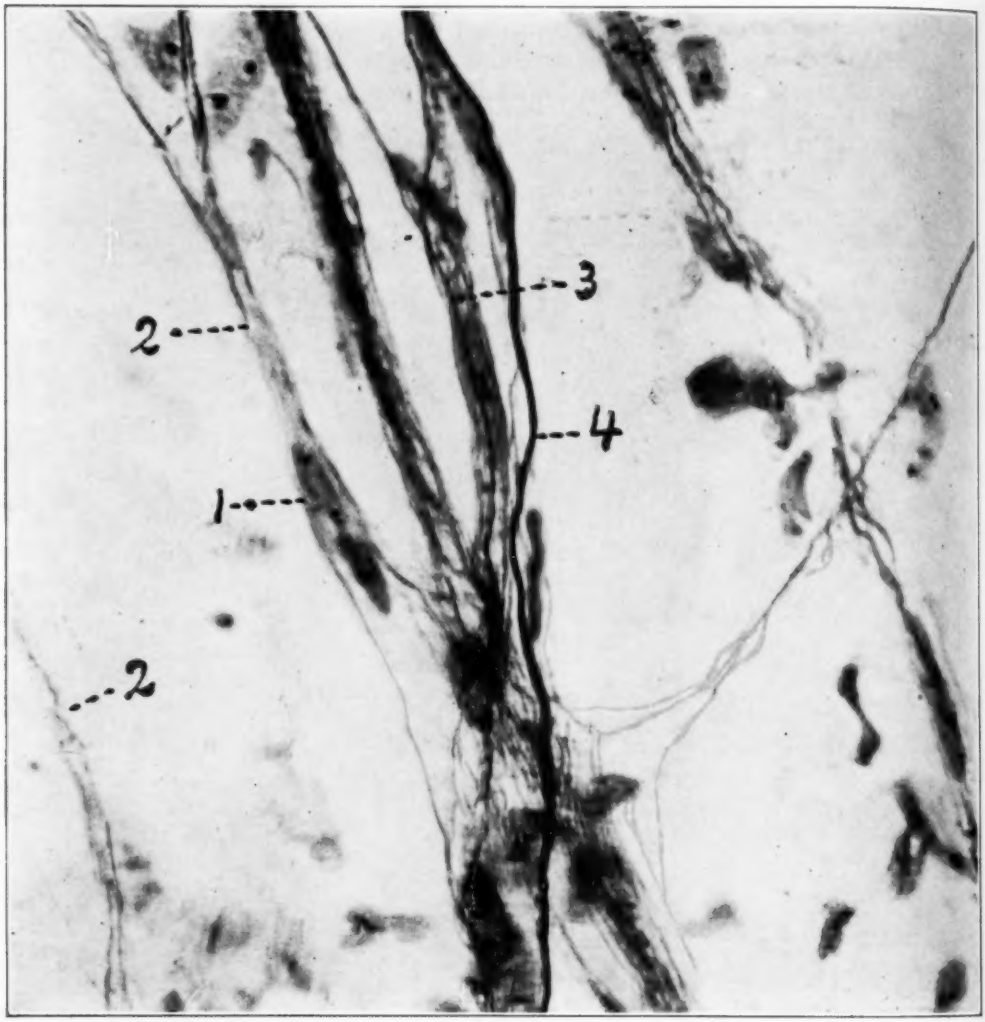

Fig. 12.—Flat section of a clear graft of sixty days. *1*, Schwann nuclei; *2*, aneuritic tube; *3*, fine new axis-cylinder; *4*, mature new axis-cylinder. × 1,100.

These regressive changes in the nerves progressed until all the axonic debris had completely disappeared. In the sixty day graft, most of the old nerves were reduced to empty tubes, the axis-cylinders having disappeared completely. These aneuritic tubes had clear margins and were formed by the Schwann sheath and nuclei. Many of the

tubes were already occupied by thin, normal-looking axons, which had invaded the graft and represent the regenerating elements that grew out from the nerves in the surrounding host cornea (fig. 12).

As stated previously in regard to the thirty day graft, not all the axons were in the same stage of degeneration. In fact, axons were still present in all stages of degeneration, although most of the nerves were reduced to aneuritic tubes or tubes that had been invaded by thin axons. The number of degenerating axons observed in the sections decreased gradually, and rare ones were still seen in grafts two hundred and seventy days after operation.

In addition to the axonic changes, there was moderate hypertrophy of the sheath, which showed the presence of fine granules. The number of Schwann nuclei had increased, and each nucleus was longer than normal; some of them were packed with many dark, round granules.

The degenerative changes in the host cornea advanced more rapidly than in the graft. Granulation and disappearance of the axons were completed here earlier than in the graft. In the sixty day graft, all the old axons were gone. No aneuritic tubes were seen. All the old nerve tubes were occupied by normal new axons, which, sprouting at the end of the normal host nerves, invaded the empty tubes (fig. 13). The Schwann nuclei showed moderate hypertrophy and proliferation.

It is evident that in no section were macrophages noted. In the distal stump of peripheral nerves in situ, the removal of the axonic debris is accomplished by large numbers of macrophages. However, a role in this function has been attributed to the Schwann cells.[18] Since no macrophagic reaction takes place in the degenerating nerves in the corneal graft, one may assume that the disappearance of the axonic debris depended exclusively on its dissolution and elimination by the Schwann cells. The changes described proceeded somewhat more slowly in the opaque than in the clear graft, although not to a significant degree.

Similar changes occurred in the nerves of corneas kept in the warm moist chamber. In vitro, however, the phenomenon passed through all its stages in a shorter period. One might ask whether the process takes place faster in vitro or whether it is delayed in the corneal graft. Comparison of our observations with those of Weddell and Glees [19] for the cutaneous nerve plexus leads one to believe that degeneration of the nerves in the corneal graft is much delayed and proceeds slowly.

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18. Ramón y Cajal, S.: Histology, Baltimore, William Wood & Company, 1933. Weiss, P.: The Technology of Nerve Regeneration: Sutureless Tubulation and Related Methods of Nerve Repair, J. Neurosurg. **1**:401-443, 1944. Huber, G. C.: Nerve Degeneration and Regeneration, in Stooky, D.: Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, W. B. Saunders Company, 1922.

19. Weddell, G., and Glees, P.: The Early Stages of Degeneration of Cutaneous Nerve Fibers, J. Anat. **76**:65-90, 1942.

REGENERATIVE NERVE CHANGES IN CORNEAL TRANSPLANTATION

When a peripheral nerve is severed, the axis-cylinders in the distal stump die and disappear. The reinnervation of the empty nerve tubes is a function that has been established as depending on the proximal

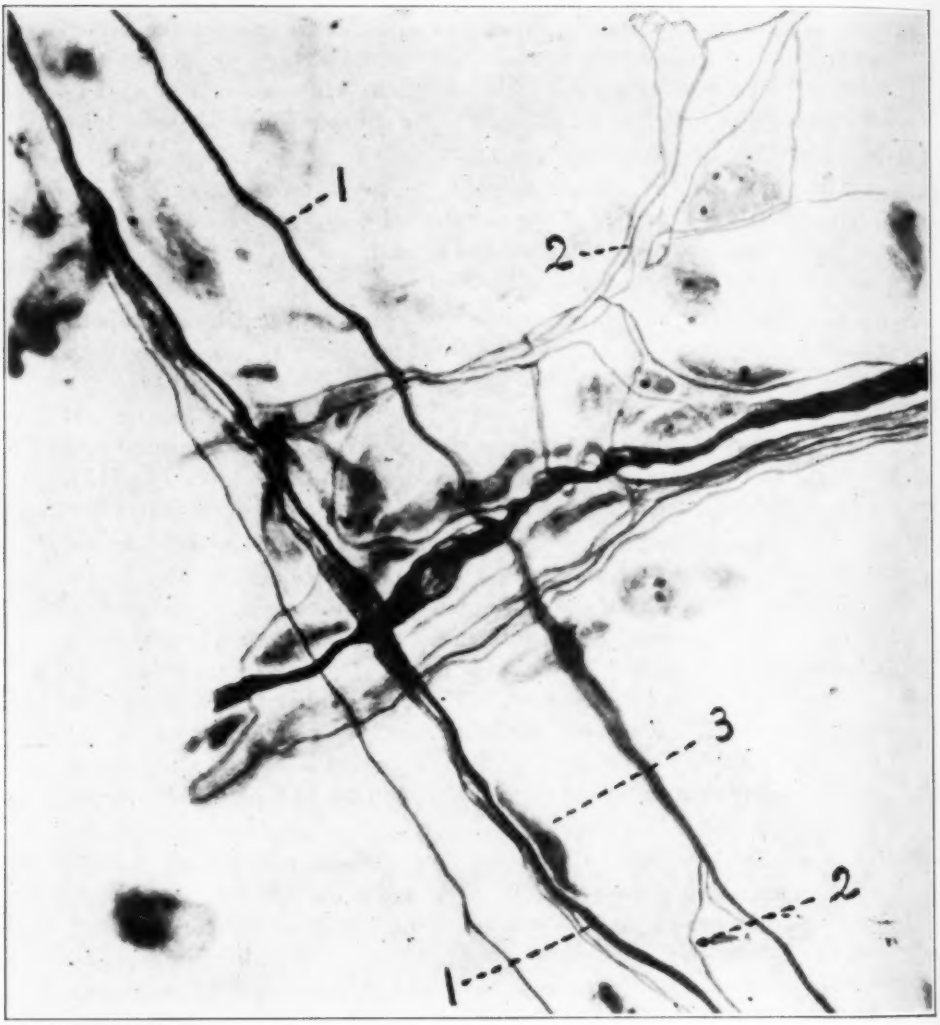

Fig. 13.—Flat section of the host cornea in a clear graft sixty days old. *1*, thick new axis-cylinder; *2*, thin new axis-cylinder; *3*, Schwann nuclei. × 1,100.

stump. In fact, the proximal stump of a severed nerve, through sprouting of its axis-cylinders, gives rise to new axis-cylinders (or axons) which invade the distal stump.

When severance of a nerve is followed by close approximation of its stumps, the newly formed axis-cylinders, having practically no

obstacle in their way, reach the central end of the distal stump quickly and penetrate it. When the two ends are not approximated, even though there is not extensive loss of nerve tissue, the down-growing axis-cylinders become dispersed in the scar tissue and penetrate the distal stump very slowly.

The new axis-cylinders are nonmyelinated, but soon they acquire a myelin sheath, which proceeds distalward. Myelination is a property of the neuron, although myelin cannot be produced except with the collaboration of the Schwann cells.

It is still a matter of controversy whether the Schwann cells precede or accompany the tip of the new axis-cylinders when these penetrate the scar tissue between the two stumps or any tissue deprived of nerve tubes. According to Weddell,[20] in most cases the Schwann cells grow first and the axis-cylinders follow them. Once the new axis-cylinders enter the distal stump, they find there the best conditions for their growth, the speed of growth being 3 mm. every twenty-four hours.

Most of the studies on nerve regeneration have been made on the nerves of the limbs of dogs, cats and rabbits. The nerves have been either crushed or severed. Weddell [21] studied the axonal degeneration and regeneration of cutaneous nerve plexuses after crushing the main dorsal ear nerve of rabbits. Reinnervation takes place more quickly after crushing than after severance; it starts later and proceeds more slowly after severance. The presence of the first regenerating fibers in an organ means that functional recovery has started. Increase in number and caliber of the new axis-cylinders is necessary before functional completion is obtained.

In corneal transplants, as in the rest of the body, regressive nerve changes are followed by progressive ones, which eventually result in complete histologic and physiologic reinnervation of the corneal graft.

As stated previously, nerve degeneration was observed in the corneal graft and in the host cornea surrounding the graft in an area about 2 mm. wide. These regressive changes proceeded more rapidly in the host cornea than in the graft. As a matter of fact, histologic preparations showed that the axonic debris had disappeared completely in the host cornea after sixty days (fig. 13). On the other hand, in sixty day grafts one could still see much axonic debris, which disappeared slowly. In grafts of two hundred and seventy days, rare degenerated axis-cylinders were still present.

The reinnervation of the corneal graft took place all around the graft. After traumatic degeneration of the nerves of the host cornea,

20. Weddell, G.: Axonal Regeneration in Cutaneous Nerve Plexus, J. Anat. **77**:49-62, 1942.

21. Weddell and Glees.[19] Weddell.[20]

an outgrowing of new axis-cylinders began at the distal end of the nerves of the host cornea. These new elements were thin and fairly straight, with a uniform caliber, and took the impregnating material evenly. They sprouted all around in the host cornea and took a centrifugal direction toward the edge of the graft. These axis-cylinders were contained in the old nerve tubes.

This outgrowth of new nerve elements was evident in the second month after corneal transplantation. It seemed to proceed normally, and in the sixty day transplant one noted, in addition to the disappearance of most of the old axis-cylinders, the presence of the new ones. All the old nerve tubes in the surrounding host cornea were occupied completely by the new axis-cylinders (fig. 13).

Figure 13 shows the condition of the nerves in the host cornea sixty days after transplantation. All the elements are represented here by new axis-cylinders; some of them have reached a diameter close to that of the normal axons; no empty tubes are seen, and the Schwann cells show practically no reaction to what is happening to the axons.

To enter the graft, these outgrowing axis-cylinders must pass through the organizing connective tissue already present at the line of junction of the graft and the surrounding cornea. Here the absence of open pathways creates an obstacle to the tip of the fiber, against which it must struggle. This obstacle exerts a manifest action on the growing tip. First, it is a retarding effect; in fact, the growth proceeds very slowly through scar tissue. The denser the scar, the greater is the obstacle opposed to the outgrowing axon. Second, the regular arrangement of the axis-cylinders is lost, and they take an irregular course. It is supposed that most of the fibers are preceded by the Schwann cells, which lay down the tracks for the axons. When the regenerating axis-cylinders reach the scar, they take a wavy course, though they still keep an orientation that has the grafts as its goal. Some fibers undergo a 90 degree bend and run along the edge of the graft. It is interesting that at the scar, when vascularization of the graft takes place, some axons take the path of least mechanical resistance by following the course of the vessels (fig. 14).

The new axis-cylinders invade the corneal graft, reinnervate it and restore its sensitivity. In the forty-five day graft, one begins to obtain some response on stimulation of the graft. Histologic sections of these grafts revealed the presence of occasional fine new nerve fibers. Reinnervation at this stage is a demonstrable histologic fact. It indicates that invasion of the graft by the new axons has started earlier, apparently after the thirtieth day. Sections of thirty day grafts showed active regressive changes without the least suggestion of new axons.

In the sixty day graft, disappearance of the old axis-cylinders was well advanced. The main feature of these sections was the presence

of new axis-cylinders. These were represented by fine, evenly impregnated threads of a uniform diameter (fig. 12). In addition to the fine new elements, some had reached a certain degree of maturation; they were thicker and more densely impregnated.

The majority of the new axis-cylinders were contained in the Schwann sheaths left empty by the disappearance of the old axons.

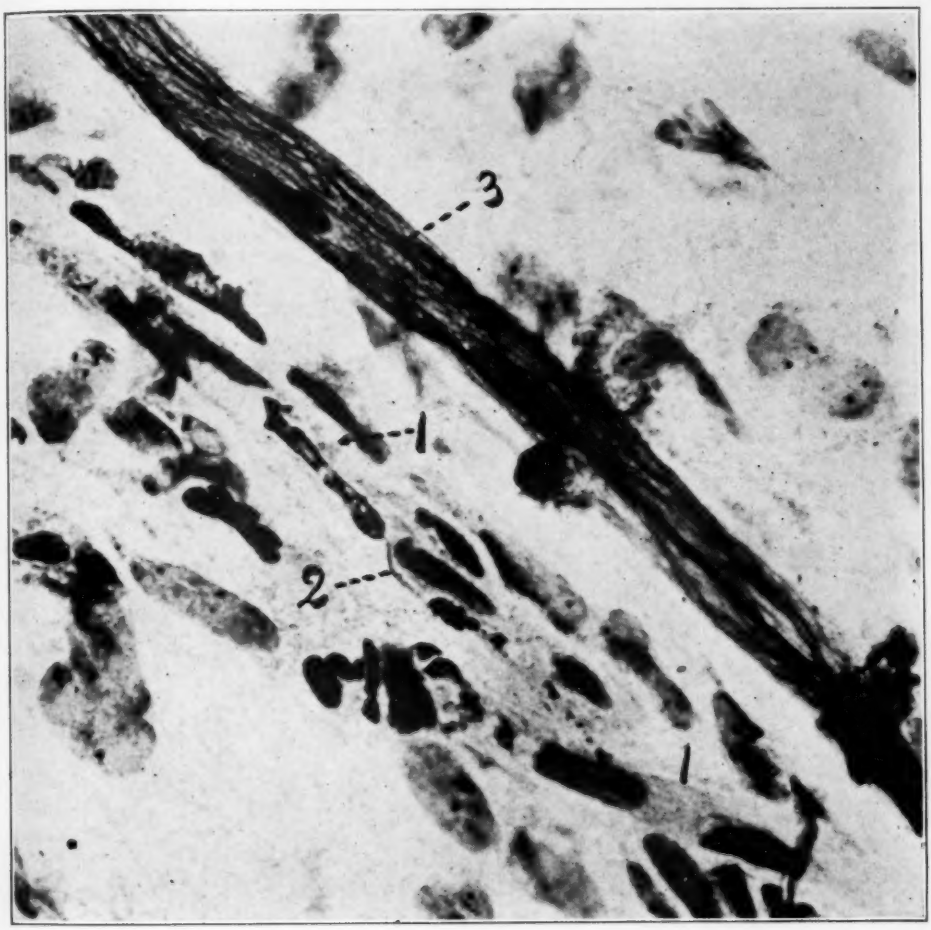

Fig. 14.—Section of a clear graft sixty days old. *1*, blood vessel; *2*, fine nerve fiber; *3*, nerve following course of the blood vessel. × 1,100.

However, some of them were naked and lay in contact with the stromal tissue of the graft (fig. 15).

Not all the Schwann sheaths were occupied by the new elements; a number of them were empty tubes, filled with an increased number of Schwann nuclei. These tubes had a clear margin. The Schwann nuclei

that filled them were more numerous and larger than normal; they retained their normal elongated shape. When the tubes had been invaded by the new axis-cylinders, the Schwann nuclei were arranged along their course.

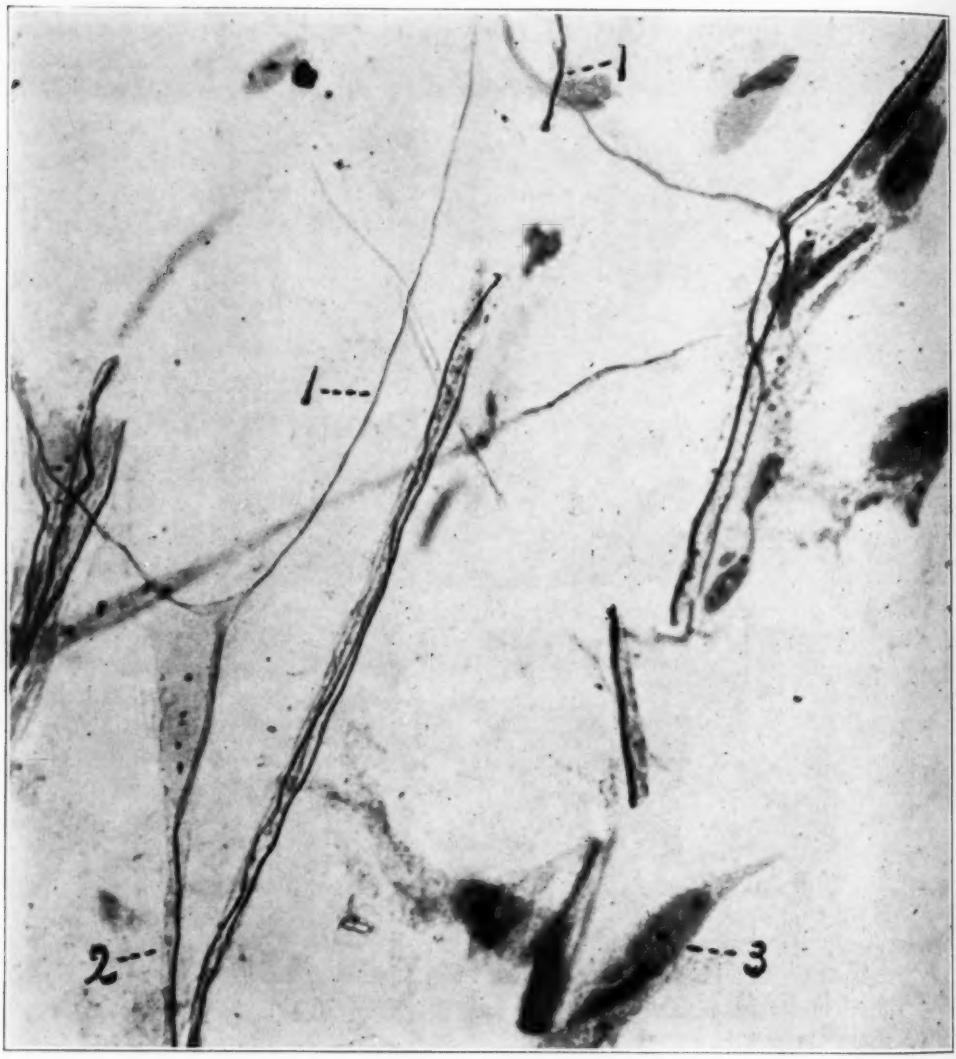

Fig. 15.—Flat section of clear graft of sixty days. *1*, naked nerve fiber; *2*, sheathed nerve fiber; *3*, corneal corpuscle. × 1,100.

Neurotization of the graft proceeds gradually. At the same time that the number of regenerating axis-cylinders is increasing, maturation takes place. Maturation consists in a realinement of the Schwann nuclei and an increase in the caliber of the axons.

Figure 16 shows a section of a translucent graft of one hundred and fifty-eight days. Here, an old nerve tube contains, besides a still degenerating axis-cylinder, three new axons which have reached a certain degree of maturation. At the same time, the number of Schwann nuclei has increased. Thus, the appearance of the new nerve elements is fairly normal except for slight reduction in their diameters.

Comparison of these changes in the clear, translucent and opaque grafts showed practically no difference in the process of reinnervation

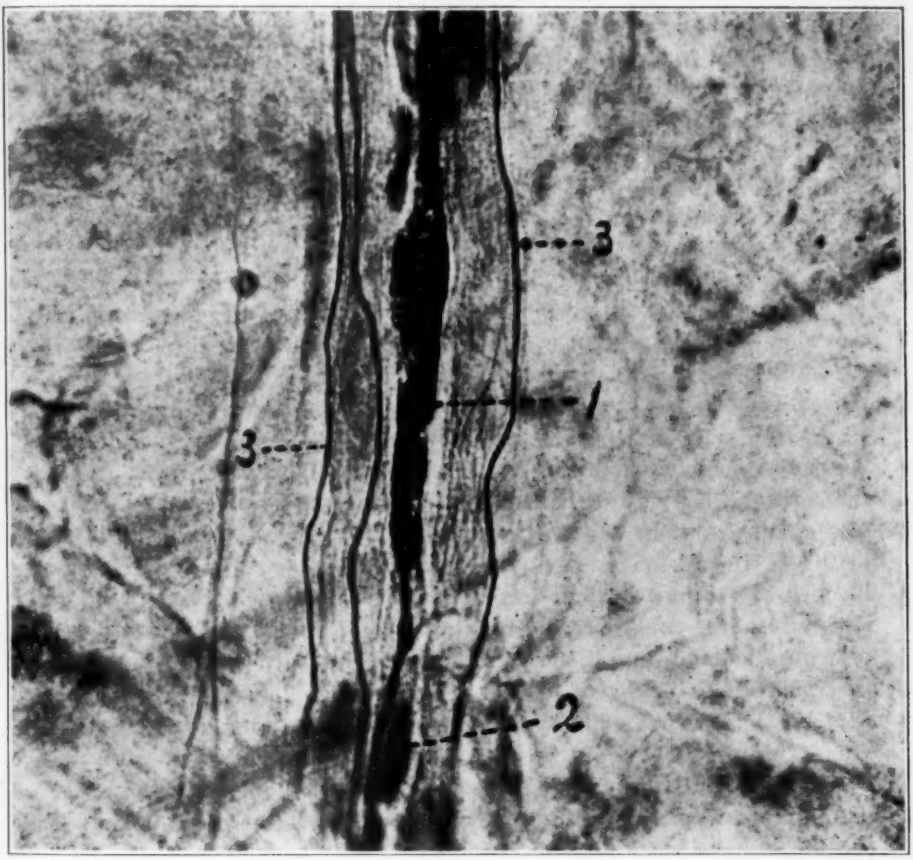

Fig. 16.—Flat section of a translucent graft of one hundred and fifty-eight days. *1*, old degenerating axis-cylinder; *2*, Schwann nucleus; *3*, new axis-cylinder. × 1,100.

except for slight retardation in the maturation of the axons in the opaque graft.

There is in the corneal graft an important factor that changes the conditions under which reinnervation takes place. In most of the experimental work on nerve regeneration, the process has been studied

after crushing or severing the nerves. The outgrowing neuraxes, after crossing the crushed area or the scar tissue between the stumps, penetrate the old, empty nerve tubes. In the case of the corneal graft, the nerve ends are far from being approximated. When the new neuraxes reach the graft, most of them find no preformed pathways to facilitate their growth. The stroma of the graft continues to present an obstacle to the outgrowing tip except when the axons penetrate the old tubes.

Reinnervation of the graft is governed by factors other than merely the impulse to growth (vis a tergo of Held). Orientation of the axons toward the center of the graft cannot be explained by contact. There seems to be a factor that guides the new neuraxes toward the aneuritic tubes and orients them to the center of the graft. These empty tubes, in addition to the supposed chemotropic action exerted on the growing neuraxes, represent the pathway of least mechanical resistance. The absence of nerves in the graft seems to stimulate the surrounding nerves to grow. Obviously, retarding factors slow the progress of reinnervation in the graft. In fact, a few fine new axons are first noticed in the graft approximately on the forty-fifth day. In the sixty day graft, besides fine new axons, some axons have reached a higher stage of development. Maturation of the new elements, as well as increase in the number of axons, continues slowly. Sections of grafts of nine months show fairly normal-looking nerve fibers.

In tests of corneal sensitivity, a dull response to stimulation of the surface of the graft appeared on the forty-fifth day. From this point, the corneal sensitivity increased until an anergic corneopalpebral reflex was obtained on the seventieth day.

From the histologic analysis, it is apparent that the graft was invaded by the regenerating axis-cylinders a few days before any physiologic response could have been elicited. Apparently, a certain degree of maturation and saturation in nerve supply is needed before a response is obtained. This latent period between anatomic and physiologic recovery has been found in general to be longer after severing than after crushing a nerve.

Maturation of the regenerating axis-cylinders conditions the progress of sensory recovery until functional completion is gained, which has a threshold lower than normal.

CONCLUSIONS

From the experimental work, the conclusion is reached that the corneal nerves behave like any peripheral nerve after its severance. The corneal graft shows regressive changes, followed by regenerative ones.

When the cornea is stored in Ringer's solution at temperatures of 2 and 37 C., respectively, the nerves undergo a process of degeneration, which passes through the usual stages. Degeneration takes place more

rapidly at 37 C., its rate being about the same as that in the distal stump of any severed peripheral nerve.

In cases of corneal transplantation, degenerative changes develop in the nerves of the host cornea and of the graft. In the host cornea, the nerves degenerate in an area 2 mm. wide around the graft; these changes are the result of direct action of the trauma exerted on the nerves by the cutting instrument; they follow a course more rapid than that in the graft itself.

In the graft, the nerves represent the distal stump of the severed corneal nerves and undergo wallerian degeneration. These degenerative changes have a rather delayed onset and progress very slowly, more so than in the distal stump of any severed peripheral nerve. They go through the same stages as those in the stored corneas, though the degeneration is still slower than that in corneas kept at 0 C.

The cornea being an avascular tissue, the corneal graft is not under ideal nutritional conditions. This apparently determines the retarded onset and slow course of nerve degeneration in the graft and the absence of macrophagic reaction.

Reinnervation of the graft is accomplished by new nerve fibers which sprout from the nerves of the host cornea all around the graft. These new fibers, passing across the scar at the junction of the graft and the host cornea, invade the graft and reinnervate it, restoring its sensitivity. Physiologic tests of the graft begin to yield a response forty-five days after the operation; the intensity of this response gradually increases but never reaches the normal threshold of corneal sensitivity. Nine months after operation, the sensory recovery has not yet reached the normal level.

Histologic study of the grafts revealed, on the forty-fifth day after operation, the presence of fine new axis-cylinders, which gradually increased in number and diameters, without reaching the normal fiber size.

It is evident that reinnervation takes place before a response to stimulation of the graft is obtained and that a certain degree of maturation of the new axons and saturation by the nerve supply of graft is necessary before a response is obtained. The improvement in the sensitivity of the graft depends on the increasing innervation and on the size of the fibers.

A comparative study of clear and opaque transplants shows no significant differences in the status of the sensitivity of the graft and in the morphologic features of their regenerating axis-cylinders.

Dr. J. L. Rodriguez Candela selected and modified the method of silver impregnation used in this work, and Mr. Max Gonzalez assisted in making the sections and stains.

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TESTS OF DEFECTIVE COLOR VISION

Reflections Based on Experience in Testing Persons With Defective Color Sense

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"COLOR," in the past ten years, has occupied with increasing intensity the minds of physicists and physiologists, as well as the military forces of the land, sea and air and industrial managements, in the effort to clear up its mysteries and to apply the knowledge obtained to useful ends. I wish to give an account of my own interest in the subject.

From my earliest years I have been interested in the "color vision" of both man and animals; even before I began to go to school, I observed that some persons who visited my home were unable to distinguish the colors of the objects about the house with the acuteness manifested by my brothers and sisters.

One striking instance repeatedly confused me. Two brothers, connections of my mother, captains of sailing ships, on their visits to us after voyages, annoyed me by their insistence on declaring that the colored objects which I offered to them were of another color than that which I had called them. My brothers, sisters and I were given small cards to register our attendance at Sunday school—four red ones for the weeks, to be exchanged for a green one to denote the month's regularity. One uncle, especially, aroused my indignation by insisting that I had not earned the green card because it was of the same color as the others; yet, as young as I was, I noticed that he was equally uncertain that the red cards (which were of a rose tint) were red. The other brother, the elder, would agree with him, but avoided disputing with us; yet he was uncertain that my maltese kitten was as gray as I maintained it to be. Being the youngest in the family, I was forbidden to dispute further. Now, these two men were expert seamen; they had run their ships during the "blockade" in the Civil War period. Later, when stringent pilot regulations were enforced, these competent sailors were refused licensing. The son of one took over his father's ship. He was a headstrong youth, who counted himself more efficient than his father, for had he "not qualified himself

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as navigator?" But he lost the ship on his third voyage out. Now, all the male members of those two families, who were intimate associates of our family, when they visited us, appeared in garish colors and seemed to lack something; yet I could not understand what it was that affected them. They would not admire the colored prints shown them. At that time, also, a Negro house servant, of whom we children were fond, could not properly sort our colored garments when they were returned from the laundry.

In my first school days, as the classes were being taught the colors and color mixings, I noticed that boys who hesitated in their naming of colors also made funny mistakes when they were directed to mix them or to define colors complementary to those called "primary."

So it happened when, years later, men were sent to me from the railroads and other transportation services, the marine and the air, I became impressed with the outward appearance of those with defective color vision and the likelihood of detecting color deficiencies even before I made ready to "test" them.

In attempting to solve the problems as they presented themselves, I, like Sir Isaac Newton, have been on my knees struggling "to count the piles of stones which I had gathered on the seashore."

A normal visual acuteness enables a person to act speedily and unmistakenly, even when unable to give the accepted names of tints or shades. I try to avoid suspecting the ability of one who declares he is "color ignorant." Once I was given the opportunity to test the sensitiveness of a group of mentally subnormal children. All had had kindergarten courses but were not fit to enter the primary classes. They had had experience in matching colored papers and strings, and none was found deficient in color vision; lamp lights and wools were rapidly disposed of by them. One day, after 2 of these boys had been examined, an old, long-experienced railroad engineer failed dismally in naming the lights correctly.

In recent years I have been greatly concerned by the much advertised attempts to correct, if not cure, so-called color blindness. In my judgment, faulty color perception is due to a congenital absence of power, as distinct a defect as are the congenital marks in a malformed eye. All attempts to relieve or to remove the visual defect are specious and bogus. The optical structures of the ocular system contain no elements for the correction of such an aberration. Such persons, however, can learn to memorize the colored plates put out by the Japanese and German observers, so that the correct naming of the plates might be accepted as qualifying them for the passing of service tests; but in actual service, when wrapped in fog and darkness, they are bound to miss out.

Sometimes I have been skeptical of the complete ability of particular observers who in times gone by have advocated certain forms of tests, and I have suspected that their own color sense was defective. Certain persons may be insensitive to red and yet have otherwise excellent color vision; and others seem to have normal sensitivity to red.

From my experience, in spite of what may already have been declared to the contrary, I am convinced that to a distinct, yet moderate, degree "color blindness" can be acquired in adult years. Chewers and smokers of heavy, strong tobaccos, especially those who drink freely of the cheaper alcohols, have manifested difficulties in color vision; their responses, however, are not such as are shown by persons with so-called red-green blindness. Their general visual acuteness, both direct and peripheral, has been found very defective. But when they were abstinent and continued under medical treatment, distinct power of color vision was restored to them, particularly those who were "rheumatic" or syphilitic. Abnormalities in color vision have been found during the course of influenza and have disappeared on recovery. Various drugs may affect color perception; thus quinine has produced inequalities in green vision and disturbance in the general threshold of color vision. Colors may appear different in daylight and in artificial light. As age advances, changes in the crystalline lenses may affect sharpness of perception.

Color vision tests are not of value as tests of mentality. In some of the Navy examinations, especially, bright youths were much slower in responding and in selecting the skeins, and other objects, than were the subjects of a lower mentality.

It has been accepted that female subjects rarely manifest "color blindness," a statement which may be true, for I have not been consulted by complaining women. In the first world war, however, there was sent to me a detachment of women applicants for Army nursing. All were professionally qualified, but were beyond the age of nurses who had been accepted for the first expedition. As I sized them up, having still my prejudices, based on appearance, I was little astonished to find that 30 out of 48 examinees were unable to match the sets of the Holmgren and the Williams skeins which had been issued; they fumbled and hesitated in quite the same manner I had observed in defective men; and, although their selections were similar to those usually made by male examinees, they were not so decisive or the distinctions so pronounced. Accordingly, I could "not recommend that they be employed in positions necessitating the recognition of colored signals." In spite of the report to the board, the women were accepted for the usual occupations of nurses, but were not sent overseas.

In my attention to suspect subjects, I have proceeded exactly as in the routine ophthalmologic study of all persons consulting me. In making

up the reports, other details were noted as having been observed. Perimetric outlines commonly varied were quite unlike those obtained in cases of retinoneural disturbances due to causes other than those dependent on deficient color sense. It might be that the responses in the perimetric tests denoted not the perimeter colors but the recognition of the presence of the targets.

Comprehension of color blindness, and, indeed, the normal perception of color, involves physiologic and psychologic, as well as physical, factors.

While it is true that the wool tests are somewhat outmoded, I have detected with these tests many a youth with defective color vision, particularly those who had learned all the German and Japanese charts. The replies of the subjects in selection of the skeins were illuminating and of value in all considerations. Beginning with the old Holmgren set, with the standards rose, green and red, the examination was followed with the Williams set, with its greater number of wools; finally, the William Thomson stick was employed, because of its simple accuracy. All the skeins selected were carefully recorded, and the examinee was given the privilege of reviewing what he had selected; when he insisted, he was given another trial, or as many as he desired until convinced that his color sense was defective. By that time he had become so confused, and his visual memory so exhausted, that his condition was readily apparent to all. It is remarkable that serious errors can be made on a simple stick consisting of only forty skeins, as devised by Thomson, the test being the result of his laborious studies extending over twenty years. For a long time he kept, carefully wrapped and noted, the myriad of skeins chosen by the examinees, from which he contrived the row of standards and the faulty skeins. Scores of the packets were preserved by him and later came into my possession; from these his decisions might have been confirmed.

I wonder what the bees' color sense might be. In following the bees in my garden during several successive years, I was impressed with the insects' steady visits to the color which I noticed their first choosing. The variegated clumps of vivid phlox offered a good field for observation. By dawn the honey gatherers might be seen already on their tours, and, as they started out, so did they continue to visit the flowers of the one color they were first seen to approach. If a white flower was first visited, only the white ones were sought throughout the tours; moreover, the bees would confine themselves to one kind of plant. Bees visiting the flowers of other colors likewise maintained their distinct choice. Bees visiting other varieties of plants kept their chosen colors as distinctly as did those visiting the phlox. No other varieties of insects maintained such a limited choice as did the bees; it was the wasps, ants and flies which caused crossing of the

pollens—to the extent that in the next season my much desired colored flowers became dull and mixed. In my observations, I had no means at hand of sequestering a bee so that I might see what it would select on its next departure from the hive. I could not seduce the bees by honey or sweets spread near the flowers; they all seemed to be impelled to pursue a definite plan of tour.

Color perception must be an intellectual manifestation of sentient animals; yet I have doubted whether the dog's mental selection of colored objects can be so much for the color, as though the color were "consciously" known to him, as for the sense of smell. All have marveled at a dog's recognition of persons at remarkably great distances, and of the occurrence of incidents beyond limited human perception.

Thus far, I have been speaking of my personal experiences. I am still at Newton's feet "counting the pebbles"; daily, as I pay homage to the small engraved portrait of him that hangs on my walls, I wonder whether I can ever understand the mysteries of the science of color vision. After forty odd years of reading and endeavors, I am, alas, still in darkness.

What is "color"? What is that which transfixes one by the sensation produced in the eye by the rays of a decomposed light? It has no synonym, and the lexicographers have had difficulty in defining it. Webster gives this definition: "A quality of visible phenomena, distinct from form and from light and shade, depending upon the effect of light of different wave lengths on the retina."

Color is not a material substance; it is a sensation perceived by the eye and is generated by waves of light emanating from an object whose image is projected to the eye. All waves have not the same frequency, and it is the variations in these frequencies which give rise to the various colors. Ether light waves have been estimated to have a frequency as great as 20,000,000,000 to 40,000,000,000,000 per second. Each color has its own frequency. In the rainbow or the prismatic spectrum, the range extends from the red end, of about 390,000,000,000 vibrations per second to the extreme visibility of violet, of about 750,000,000,000,000 vibrations per second. Between these two ends of the spectrum, the human eye is capable of distinguishing orange-red, orange, orange-yellow, yellow, green, green-blue, cyan blue, blue, violet-blue and violet.

Light due to waves of one simple frequency would produce the simplest color sensation; but homogeneous or monochromatic light is not possible to obtain because all color waves are compound. For instance, when sodium is burning, it emits a yellow light; yet that light is the compound of two yellows of separate frequencies but so close together as to become almost monochromatic. However, the human eye can receive compound waves of vibrations so close as to

form a single recognized color, the separate waves impinging so close together on the same spot on the retina as to blend the rays and thus give rise to that single color. The retina can perceive all waves from the red end of the spectrum to the opposite (violet) end. Colored lights are admixtures of several monochromatic colors, which the retina so blends as to give rise to a single sensation.

White light in general depends on the simultaneous compounding of all visible wave frequencies. In addition, it is possible to obtain whiteness by admixtures of certain separate colors, such as ultramarine blue and yellow; red and greenish blue; greenish yellow and violet; orange and greenish blue. Such colors are spoken of as complementary colors. It is a singular fact that when such pairs of solid pigments are mixed they do not produce white; for example, when blues and yellows are mixed, green is produced. However, when complementary colored lights are shown simultaneously to the eye, they always produce a white light.

Colors vary in hue, in purity and in luminosity—the hue names the color; the purity, by the absence of white light, the depth of the color, and the luminosity, or brightness, the shade or tone of the color. Thus, as white is mixed with a color, the color may become "brighter," and if black is mixed, "dulness" follows—its luminosity fades. When a modified product is mixed with its pure complementary color, the result is not white but gray.

An analysis of the Young three component theory and the adaptation of von Helmholtz' pursuit of it, I acccepted at the beginning as the groundwork of my studies.

It is of the greatest importance that the existence of color deficiencies be recognized.

There are many grades of "color blindness"—some persons are incapable of distinguishing the densest of red, or green, or blue, or even yellow. Others perceive these colors as through a hazy veil. Some persons may be defective in distinguishing only one, or at most two, colors; others, three or four. There are rare persons who see a colored picture only as though it were a black and white engraving; these persons have so-called monochromatic color vision. Accordingly, the various types of color blindness are usually described with regard to the number of colors definitely perceived and correctly named.

It has been interesting to note how persons with defective color vision adapt their perception to their needs; and few deal in colors. In their early years they learn what other people accept as the various colors, and, cautiously, they keep within those bounds. They seek to hide their defects. In childhood they have learned of their dissimilarity to their fellows, and they avoid necessity for color choosing. At the same time, their direct visual acuteness may be of the highest degree and range.

Of 230 boys in the upper classes of their school, 11 were found to have defective color sense; 1, the victim of hypophysial disease, had monochromatic vision. I endeavored to impress on the boys with defective color vision that they should not aspire to occupations, professions or positions requiring accurate perception of colors. In particular, they should not hope to become "fliers."

Color-blind persons seldom refer to their defects; rarely are they "vivacious." I have noticed how dull their mien is. By analogy, they remind me of trained singers whose tones lack something; they cannot keep exactly "on the key." I once knew a singer whose song selections were charming, but who avoided singing extemporaneously. He never joined in a hastily assembled quartet but offered, eagerly and readily, to sing the songs he had learned and prepared for.

Two patients with deficient color sense once took my attention. One was a capable chemist whose judgment of certain newly experimented-with compounds required exact estimation of their color. He was unable to match satisfactorily new compounds with the color of the standards. Another was a wallpaper designer. He was one of a family, largely of male members, with several generations of designers. The men of the family, therefore, were in close direct descent, but they had married into various families. The lad's skill in black and white was all that his father and grandfather demanded, but when delicate neutral colors were used he failed so sadly that he could no longer carry on the family tradition.

Every now and then there has come to me a young medical man desirous of entering ophthalmologic practice who has found it impossible to harmonize his description of the ocular fundus with the colors described by his chief. The eyegrounds resembled those obtained with red-free lights. These men remembered their difficulties in distinguishing the various stains in their earlier histologic courses.

I have known a few persons with unilateral color deficiency. It may be that persons with this condition are more numerous than has been reported. It is possible, also, that more precise investigation might yield interesting information concerning the whole subject of color vision. In the examination of railway men, I have tested each eye separately, both as a matter of precaution and with the possibility in mind of the presence of unilateral color blindness. A person with unilateral defect in color vision is unsafe, for if while in traffic he were to have one eye out of commission the defect might then become manifest.

The spectrum has been a useful instrument, with its six colors—red, orange, yellow, green, blue and violet. Indigo is sometimes included. To the normal persons all colors are distinct, from the red end to the violet end; but to others the red end, or the violet end, is cut off, so that

one appears black. In my experience, the red end had been most often affected. Two types of defective subjects have commonly been found—one perceives a full length spectrum, but with dull ends; the other perceives a spectrum with shortened ends. These types have been found among persons who long have been classified as having red-green blindness. Later, as now, their defect came to be spoken of as "protonopia," for red blindness, and as "deuteranopia," for green blindness. All sorts of deficiencies have been defined, from blindness in which only blue and yellow are perceived to a simple diminished sense of redness, in which the red, when vividly illuminated, may fully be perceived. Such a sense is then spoken of as anomalous. A person with anomalous trichromasy requires red and green to be concentrated, and he should be advised against seeking employment in occupations likely to become dangerous to life and safety—in conditions of mist, fog and smoke, or even agitation—as his responses might lead to disastrous consequences. I regarded the results obtained in examination of the recruited Army nurses as indicative of "anomalous trichromasy." One set of skeins they spoke of as being "dull," which may have been true, for the skeins were not as clean as were the skeins on my Thomson stick.

Subjects with anomalous trichromasy are really in the "dangerous" class and should be studied with the greatest care. They have aroused all my efforts; yet it has not always been easy to discuss their deficiency with them. But by carrying out a variety of tests, and by more or less fatiguing the suspected subject, catching him at his lowest ebb, one can impress him with a knowledge of his weakness. A normal person cannot become fatigued by such tests.

In my early experience, I was impressed with the subject's insistence on picking up the wools or the colored plates to examine them, as though he were myopic, even smelling them, and then laying them down cautiously, as though they were fragile and easily broken. Defective art students have presented characteristics peculiarly their own. They learn the appropriate colors to use for objects, such as green for trees and foliage and blue for skies, so that their product might readily be passed by the teacher. I have often wondered whether "impressionists" may not have had defective color vision. A noted artist, whose black and white or sepia studies had been awarded the highest honors at the Academy, aspired to be a portrait painter. Without his box of labeled colors, he was set to prepare an oil landscape. The picture he presented, though perfect in outline and design, was colored beyond description, at which his fellow students derided him. He was directed to pursue only "black and white drawing," in which he was successful, becoming a distinguished book illustrator. Though he is now dead, his works are still given high praise. I

learned that his father was well known for his pen and ink drawings and for his etchings, but no oil paintings have been ascribed to him.

The results obtained with "shadow tests" are hardly reliable; as they are really nothing but shadows, much might obstruct their being viewed and thus interfere with their clearness. To the subject with normal sight they can be of interest, for instance, if the specific color can be blocked out, the complementary color may appear followed by the after-image, to be named by the examinee. The color-blind subject easily becomes confused, as all sorts of variations result, blues and yellows appearing as green, red-green as red or gray and green-red as red or gray.

In my private practice, I have employed the simple Thomson stick as a swift trial test. The speed and accuracy with which the examinee responds have served as an index of what to expect during a more prolonged examination. The Williams lamp, with its one to three roundels of various diameters, is employed with railway men. The men's confidence can thus be gained, and they are disposed to acquiesce in further questioning. The Edridge-Green lamp, in which the intensity of the reflections can be varied, is employed if there is hesitation or only deficiency. To the color-blind subject, a change in illumination produces a change of color. The simple Thomson lamp, with two disks, one of standard lights and one superimposed to modify the standards, has then been used. Despite the simplicity of this lamp, many a man has failed, the results being admitted and confirmed by his fellows who came to witness the testing in his behalf.

Then I use the so-called Japanese (Ishihara) pseudoisochromatic plates, which display numerals or splotched backgrounds, and the Stilling charts, which contain a greater number of plates than the Japanese. Certain of the Ishihara plates show an arrangement of the splotches which to normal subjects are not numerals, but the subject with defective color vision promptly gives them a number, or an outline is traced making a different figure than that presented. The first three or four plates are sufficient to judge the normal subject and others who view the spectrum. From the replies made to the remaining plates, one can be told whether or not they are expressing deficiencies in red-green vision. The Rabkin polychromatic tables are similar, displaying squares, cubes and triangles together with numerals; these have been, of distinct service to the Russians but are not now obtainable.

In recent years there has been much used a series published by the American Optical Company, based on the Ishihara plates. This series contains a greater number of plates than any of the Ishihara editions. Many active young men committed these plates to memory and glibly rattled off their replies. Persons who offer to cure color blindness depend on their teaching the testee to memorize the plates. The

numerals are of a more pronounced shade than are the backgrounds, so that they exhibit a distinctness which fades when the background is of the same shade; the numeral is then no longer visible. Munsell's "Book of Colors" has been much employed. It consists of many plates adopted by the National Bureau of Standards to serve as the standard of the hue of all the colors used in the arts and industries. Edridge-Green devised a set of plates splotched and lettered somewhat like the Isihara and Stilling plates.

As a final test, I supply the wool skeins. By this time the man is exhausted, and it is then that his mistakes appear. Thomson's original stick held forty tagged and numbered skeins; the true skeins bearing the even numbers, 2 to 40 and the "confusing" skeins the odd numbers, 1 to 39. The sequence of the numbered skeins might have been learned, but it was sad to see an examinee endeavor to carry on his selections when the skeins were mixed on the stick, so that the groups corresponding to the rose section, the green numbers and the red numbers were arranged in a disorderly fashion, when the man's confusion became instantly manifest. The Jennings test is occasionally employed; this consists of true and confusing skeins, affixed to a card; beside each is a hole in the card, and under the card is a printed sheet, which is punched by a pointer, thus registering the true or false selection, the sheet thus serving as a record. In cases in dispute the Nagel anomaloscope or the simpler Chibert chromatophoroptometer may be used.

Color blindness, according to accepted descriptions, has been divided in three classes, or varieties. The first, or red-green blindness, is of the greatest importance, as signals on the highways, on the railways, in the air and at sea are red and green. The second class is that of persons who find it difficult to distinguish blue and yellow but who can perceive red and green. These colors are not of so great importance, except in some industrial and artistic employments. The third class is monochromasy; this type may occasionally be complained of by female subjects. Red-green type of blindness is found in male subjects, who have inherited it from male forebears, both directly and by transmission through the female members of a defective family. It may skip a generation and reappear in sons, conspicuously so, if the affected female carrier has married into a defective, but presumably unaffected, family.

Persons with red-green blindness commonly distinguish only the blues and yellows—they are classed as "dichromatic." Not all persons are affected with respect to the same colors, and to equal degrees. Their appreciation of the spectrum is various, and the bands are differently described; thus, they may be able to count all the bands but be decidedly uncertain about them.

While present day reports give a greater percentage of cases, I do not believe that color blindness is increasing; rather, investigation with improved methods has detected persons who in ordinary affairs have given no indication of their defect. According to earlier estimates, the percentage of affected males was 3 to 4; yet it has been found by several observers to be 9 per cent, and by another, 11 per cent!

"The color blind" is a somewhat unkind term applied to persons who are unable to distinguish certain colors correctly. It was introduced by Brewster about 1830, but it is not so cruel as the term "daltonism," after Dalton, the English chemist, who suffered from the defect. More recently, it is spoken of as "achromatopsia."

Despite the growing interest in the examination of persons who are believed to be normal, no new facts have been discovered in recent years which will aid in the solving of the problem of color vision. The theories are as fiercely contended by their advocates as ever. The various test methods have served to estimate the number of cases for each class of the responses. The history of color blindness is fascinating. Some day one may learn that the sense becomes manifest through the action of light on the chemical constituents of the retina.

317 South Fifteenth Street (2).

IRIDOTASIS AB EXTERNO FOR RELIEF OF GLAUCOMA SIMPLEX

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THE PURPOSE of any operation for glaucoma is the reduction of intraocular tension, and to accomplish this at least one of three results must be accomplished: (1) The normal intraocular pathway of drainage must be restored, (2) a new intraocular pathway opened or (3) a pathway formed for extraocular drainage. Many types of operations have been devised to accomplish these objectives. Of the first class, that is, operations devised to restore the normal pathway, iridectomy with its various modifications is the chief example. Cyclodialysis was thought by Heine, its originator, to accomplish the second objective, the opening of a new intraocular pathway; and, while experimental work on rabbit eyes which I did several years ago failed to confirm his claim, gonioscopic examinations have demonstrated an opening in the iris angle in successful cases, indicating a fistula of the suprachoroidal space. The operations which have been done to produce pathways of extraocular drainage are the most numerous. Many have died a natural death. The chief survivors are Elliot's sclerocorneal trephination, Herbert's sclerectomy, LaGrange's iridosclerectomy, Holth's iridencleisis and Borthen's iridotasis. Of these, Elliot's trephination has undoubtedly been the most popular, but in the last few years iridencleisis has grown in favor.

Until three or four years ago I practically always performed the sclerocorneal trephination for simple glaucoma. This operation was not always satisfactory, however, as in some cases the filtering bleb would flatten down and become adherent or the trephine opening would close over with scar tissue and the tension would rise again. In some cases the bleb would become too large. I also had a few cases of quiet iritis or cyclitis. Another danger is in getting the flap too thin. I, therefore, gave a great deal of thought to devising some method of eliminating these difficulties. It had been my practice to perform iridectomies for acute glaucoma through a scleral incision after reflecting a conjunctival flap. I believed that if I could combine some type of

Read at a meeting of the Columbus Ophthalmological and Otolaryngological Society, Oct. 7, 1946.

filtering operation with the iridectomy in order to maintain a permanent filtration channel, this procedure would meet the requirements for relief of tension in chronic simple glaucoma. To accomplish this result, I have been doing a partial iridectomy through a scleral incision and inserting a tongue of iris tissue into the angle of the wound. Similar operations have, of course, been done before, but my experience with the operation described here has been so satisfactory that I should like to describe it again.

I have performed the operation in approximately 100 cases in the past two or three years, with almost universal satisfaction. In 3 or 4 cases of hemorrhagic glaucoma the results were not satisfactory and it became necessary to enucleate the eye.

Of course, the cases should be selected, as the operation is contraindicated when the iris is inflamed or the iris is atrophic. Synechias are likely to prevent a satisfactory incarceration of the iris. The operation may be performed either with general or with local anesthesia. I prefer "pentothal sodium" anesthesia, and if the patient is not arteriosclerotic, I usually give a retrobulbar injection of procaine hydrochloride–epinephrine hydrochloride solution to lower the intraocular tension.

If the operation is done with use of a local anesthetic, a subconjunctival injection of procaine hydrochloride–epinephrine solution or 2 per cent cocaine is given above the limbus. A conjunctival flap is then dissected down to the limbus, much as though a sclerocorneal trephine were to be done. The flap is held forward, and a scleral incision *ab externo* is made with a Tooke knife or a small scalpel, beginning 2 to 2.5 mm. posterior to and paralleling the limbus. The knife should be so directed that the globe is entered about 1.5 mm. posterior to the limbus. This brings one down on the root of the iris, a fact which is extremely important. As a rule, the iris begins to prolapse as soon as the anterior chamber is entered. The incision is carefully and slowly enlarged until it is 6 or 7 mm. in length. The prolapsed iris is then grasped and withdrawn sufficiently to permit a meridional incision with scissors, which should include the pupillary margin. This incision is made at one extremity of the incision, and the surgeon, without releasing the grasp of the iris, tears the latter across. The tongue of iris tissue is then incarcerated in or wedged into the opposite end of the wound. If desired, an iris repositor may be used to secure the tongue of tissue in place more firmly. The iris pillar at the site of the meridional incision is replaced by massaging the edge of the wound externally by means of a repositor. The flap is then replaced and a running silk suture inserted to hold it in place. Blood is prevented as much as possible from entering the anterior chamber by using epinephrine and by holding the tip of a sponge over the incision. It is not always possible to prevent some blood from entering the anterior chamber; while this is undesirable, I have never seen any complications from it, as the blood has always been absorbed in a few days.

Occasionally peripheral adhesions of the iris or the synechias at the pupillary margins prevent prolapse of the iris, in which case a spatula may be used to break the adhesions or the flap may be pulled forward and the iris forceps inserted into the anterior chamber to grasp the iris.

Some surgeons caution against the use of atropine in iris inclusion operations for fear of pulling the tongue of iris out of the scleral wound. In my opinion, this fear is unwarranted, and I routinely instil atropine for a few days, until the postoperative reaction has subsided. Later, if the tension is a little slow in returning to normal, as occasionally happens, I may instil pilocarpine and employ gentle massage of the globe.

In my opinion, the advantages of this procedure over sclerocorneal trephination are as follows: 1. It is less difficult to carry out. 2. Each step is under perfect control; as a consequence, there is less danger of encountering difficulties, such as too thin a flap, buttonholing of the corneal flap or incomplete removal of the trephine button. 3. By performing the iridectomy through a scleral incision, the difficulty encountered with a shallow anterior chamber and the danger of injury to the lens experienced with use of instruments are obviated. 4. The eye is left in a safer condition and in less danger of secondary or late infection, such as sometimes occurs after trephination. 5. And of great importance, the root of the iris at the site of the iridectomy is removed, thus reopening the iris angle so that no iris tissue is left to push forward against the cornea and close the angle again. 6. By incarceration of the tongue of iris tissue in the scleral wound a permanent filtration channel is formed. It will be noted that, by 5 and 6, two of the three objectives in operating for glaucoma are accomplished in the one procedure.

As to the disadvantages, some persons may object to the keyhole pupil, but if its use results in reduction of tension and maintenance of sight, I do not consider it a disadvantage. Others feel that incarceration of iris tissue in a wound is poor and dangerous surgical technic; there is a great difference, however, between deliberate incarceration of a tongue of iris, including the pupillary margins, with which method there is no pulling or tugging on the iris and the tissue is constantly bathed in aqueous, and the accidental incarceration of iris tissue in a wound, in which case the tissue is usually in the form of a diverticulum from the posterior chamber without filtration and with a resulting cystoid scar, which remains irritable and is irritating to the contiguous ciliary body.

As I have said, my results with the procedure described have been almost uniformly satisfactory.

21 East State Street (15).

A TANGENT SCREEN ILLUMINATOR

Construction, Use and Advantages

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AND
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THE LUCKIESH-BERENS tangent screen illuminator previously demonstrated [1] was developed to provide for the lighting requirements necessary in the study of central visual fields with white and colored test objects. The illumination formerly proposed [2] was found to be lacking in some essentials for scientific work and for the comfort of the examiner. The general specifications established for the unit were as follows:

1. The illuminator should provide continuously variable illumination of from 1 to 100 foot candles.

2. It should contain a means for quickly checking and adjusting the level of illumination.

3. The level of illumination in the 25 degree zone of a tangent screen located 75 cm. in front of the illuminator should not vary more than 10 per cent.

4. The quality of the light should approximate that of daylight in order to minimize distortion of color.

5. The color or spectral character of the light must not change as the level of illumination is varied.

6. The entire unit should be simple to operate and should require a minimum of maintenance.

7. There should be no necessity for tedious calibration of the device as the lamps deteriorate or when they must be replaced.

8. Generated heat should be reduced to a minimum.

Construction was aided by grants from the John and Mary R. Markle Foundation; the General Electric Company; the Ophthalmological Foundation, Inc.; the Department of Research of the New York Eye and Ear Infirmary, and the Department of Ophthalmology, New York University School of Medicine.

1. Berens, C., and Luckiesh, M.: The Luckiesh-Berens Tangent Screen Illuminator, read at the meeting of the American Academy of Ophthalmology and Otolaryngology, Chicago, Oct. 15, 1946.

2. Berens, C.; Kern, D., and Payne, B. F.: A Tangent Screen with Artificial Daylight Illumination, Am. J. Ophth. **17**:826-833, 1934.

CONSTRUCTION

The final design of the illuminator is shown in figures 1 and 2, which are front and rear views, respectively. The instrument consists essentially of a hollow square with fluorescent lamps mounted in white channels. These are covered with a system of adjustable sliding

Fig. 1.—Front view of the tangent screen illuminator. The photocell is in position for measuring the foot candles on the tangent screen, and the operator is shown adjusting the illumination. The illuminated meter, *M*, can be seen in the upper right corner. The switches which control the fluorescent lamps are on the right hand base, convenient to the operator.

louvers for varying the illumination. The lamp channels forming the illuminating unit are 6 inches (15 cm.) wide and 2 inches (5 cm.) deep. Two 36 inch (90 cm.) fluorescent lamps are placed side by

side in the channels on each of the four sides of the hollow square. This provides a total of eight lamps in the unit. The lamps are so connected that all are used for the higher levels of illumination, but only four are used for the lower levels. Two switches, an "on-off" and a "high-low," placed on the base of the right hand standard, control

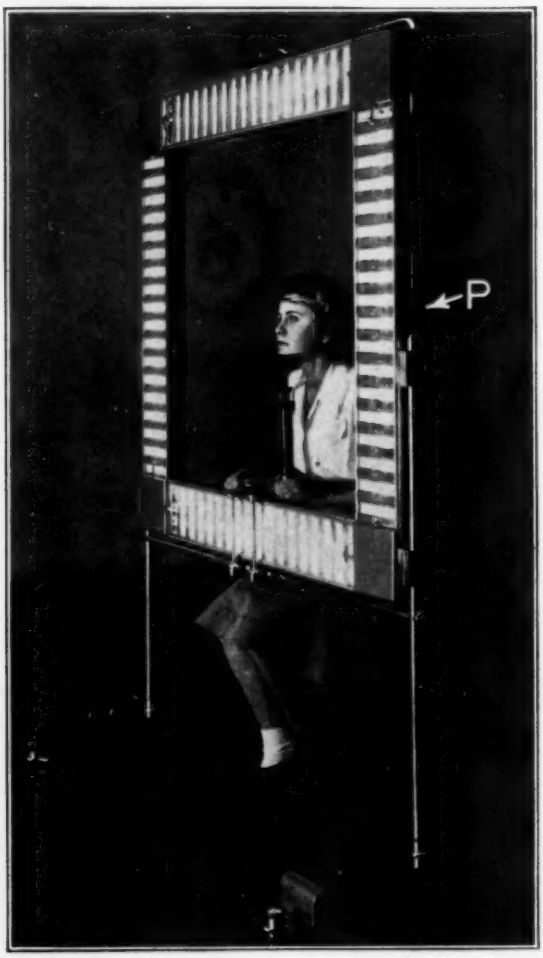

Fig. 2.—Rear view of the tangent screen illuminator, showing the louvers nearly fully open. The photocell, *P*, is in its retracted position at the right of the illustration.

the number of lamps being used. The level of illumination on the screen may be varied in infinitely small gradations from approximately ½ to 100 foot candles.

Thirty watt, 4,500 degree white fluorescent lamps are used. These provide an excellent color quality of illumination for viewing colored

test objects used in the determination of visual fields. Considerably less lamp wattage is required with fluorescent lamps than with filament lamps. This is an important factor in reducing the generated heat. The total wattage consumed by the unit, including the losses in the ballasts, is only 280 watts, as compared with over 2,000 watts if filament lamps were used.

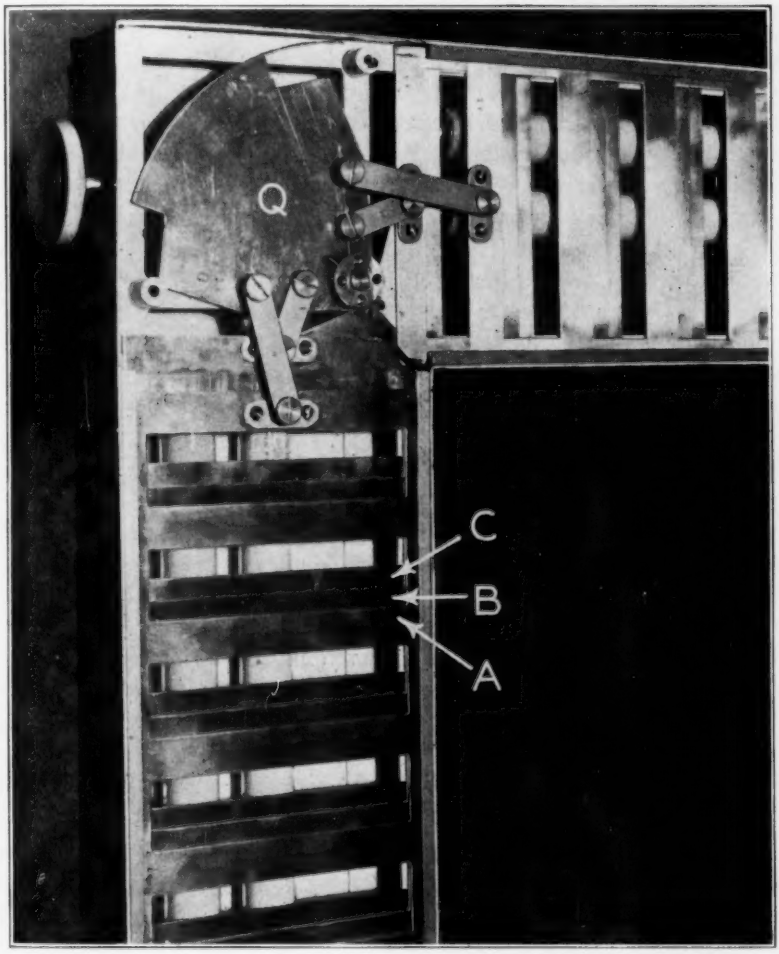

Fig. 3.—Close-up view of the mechanism at each of the four corners for controlling the position of the louvers. All are operated simultaneously with the knob shown at the upper left corner.

A photocell, mounted on an arm, may be rotated outward and the cell placed in the center of the screen for measuring the illumination. In figure 1 the photocell is shown in the position for adjusting the illumination of the screen to the desired intensity, measured in foot candles.

In figure 2 the photocell, *P*, is shown at the left in the retracted position when not in use. The illumination is read on an illuminated meter, *M*, shown in figure 1 in the upper right corner of the unit. Two scales, measuring 0 to 10 foot candles and 0 to 100 foot candles, respectively, are available and may be selected by a switch directly below the meter. Thus, all controls are readily accessible to the operator at the right hand side of the unit.

A knob at the upper right corner of the illuminator (fig. 1) controls the position of the louvers. Figure 3 illustrates the control mechanism and the louvers, as well as the position of the lamps in the channel. The quadrant, *Q*, is rotated by means of a worm and gear mechanism. An accurately designed system of links slide the top and middle louvers, *A* and *B*, respectively, over the bottom, or fixed, louver, *C*. Identical quadrants and links are used in the four corners of the illuminating unit. The worm and gear control permits accurate adjustment of the level of illumination. The use of a series of three louvers, instead of two, permits greater light output, and yet the mechanism is relatively simple. The size of openings in the louvers is dependent on the movement from the fully open to the fully closed position. With two louvers, the open area would be less than 50 per cent of the total area because of the necessity of overlapping in the closed position. With three louvers, the open area is approximately 65 per cent, with a corresponding increase in available illumination.

Fluorescent lamps have a long, useful life. On the rare occasions when it is necessary to change the lamps, they are reached from the rear of the unit. When the back plates are removed, the backs of the four hinged lamp panels are exposed. The release of two rotary catches permits each panel to be swung outward, bringing the lamps into position for easy cleaning or replacement. In figure 4, two of the back plates have been removed, and one of the lamp panels is swung outward. The fluorescent lamp starters may be changed without removing the back plates. They are exposed (fig. 1) in pairs on each of the four slides of the hollow square.

The illuminating unit, with its center 48 inches (120 cm.) from the floor, is supported on two heavy vertical rods, each rod mounted on a heavy plate. The entire device is 6 feet high (180 cm.) and 4½ feet (135 cm.) wide. Two large adjusting screws for leveling the instrument are incorporated in each base. Two two-lamp fluorescent ballasts are mounted in each of the two bases, and each is covered with a housing.

An adjustable forehead and chin rest is mounted, as shown in figures 2 and 4. A sliding adjustment provides for varying the distance from the eyes to the screen.

The illuminating unit and the base covers are finished in a taupe-colored baked enamel, which is similar in appearance to a hammered finish. The louvers are of aluminum. All other surfaces, except the support rod of the chin rest, which is black lacquer, are chrome plated.

The distribution of illumination on the tangent screen is approximately the same for all levels of illumination from 1 to 100 foot candles.

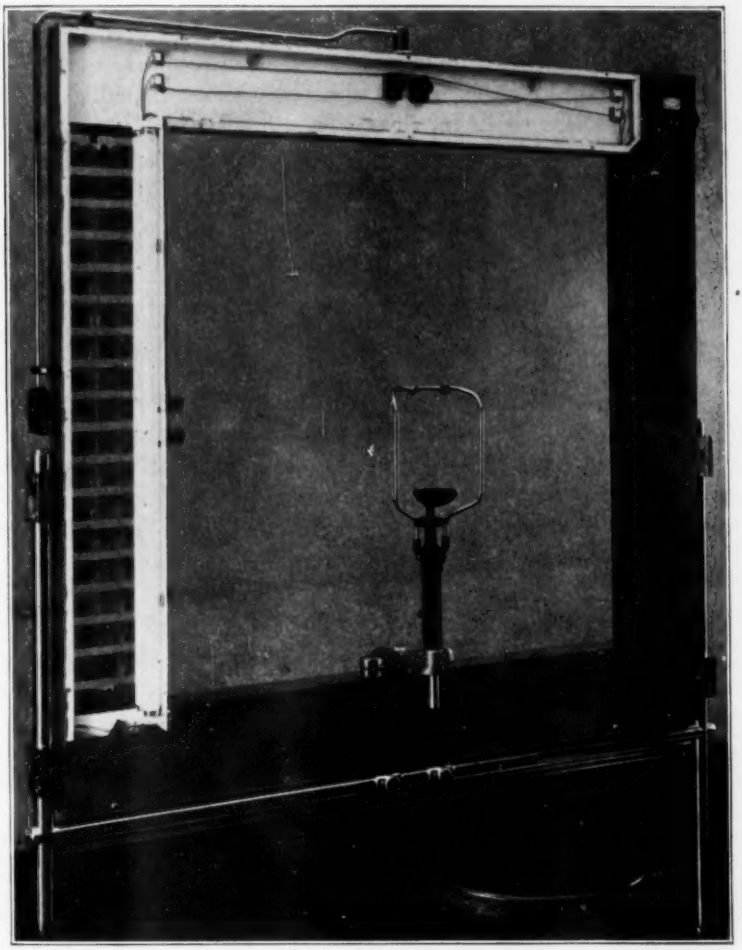

Fig. 4.—View showing two back plates removed and one hinged lamp panel swung out to illustrate accessibility of the fluorescent lamp. The slide adjustment of the head rest mount also can be seen.

With an illumination of 100 foot candles in the center of the screen, the illumination varies from 100 to 102 foot candles in the 25 degree zone and from 102 to 90 foot candles in the 35 degree zone. Thus, in the important central area, the illumination is essentially uniform.

SUMMARY AND CONCLUSION

A tangent screen illuminator has been developed which because of the increased illumination available (100 foot candles) may be adapted to the examination of central visual fields with any tangent screen or surface. The illuminator was constructed especially for use with a neutral gray screen.[3] It permits charting from the front surface and the use of spherical colored test objects.[4]

The illuminator has been found to have the following advantages:

1. It provides variable illumination of from 1 to 100 foot candles, which may be rapidly checked and adjusted without changing the color or the spectral character of the light.

2. The illumination is quite uniform over a screen 2 meters in diameter, and there is only a 10 per cent variation in the central 25 degree zone.

3. The quality of the light approximates daylight sufficiently for accurate testing with colored test objects.

4. The apparatus is simple to operate and to maintain, and tedious calibration is minimized because of the built-in light meter.

5. The low intensity of heat generated makes the patient and the examiner more comfortable.

This tangent screen illuminator was designed and built in the Lighting Research Laboratory of the General Electric Company at Nela Park, Cleveland, where A. A. Eastman and S. K. Guth contributed much toward this satisfactory solution of the many problems involved.

Nela Park, General Electric Company (12).

301 Fourteenth Street (3).

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3. Footnote deleted on proof.

4. Berens, C.; Evans, J. N., and Kern, D.: White and Colored Spherical Test Objects for Use in Campimetry and Perimetry, Tr. Sect. Ophth., A. M. A., 1931, pp. 407-409.

AMBLYOPIA EX ANOPSIA

A New Concept of Its Mechanism and Treatment

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LOS ANGELES

THE PURPOSE of this paper is to present a new concept of the mechanism of amblyopia ex anopsia. It is hoped that the old theories will be reviewed and their present credence evaluated. Medical dictionaries and standard ophthalmologic texts perpetuate the definition of amblyopia ex anopsia as that amblyopia resulting from disuse of an otherwise normal eye. This point would be of academic importance only were not treatment of this condition involved which brings about improved results. This treatment hinges on acceptance of a new concept.

The following definition is offered as being closer to the actual conditions and therefore more tenable: Amblyopia ex anopsia is poor vision resulting from deviation of the visual axis from the fovea centralis to a point elsewhere on the retina where vision is less acute. It may be said that the greater the distance from the fovea, the less the visual acuity of this amblyopic eye as tested by ordinary means.

Before the analysis and the basis for the argument are presented, it may be stated that this discussion is centered about the experience in about 200 cases of amblyopia ex anopsia in private office practice during the several years following 1934. While granting that the number of cases may not be as great as desired, and that this experimental material does not lend itself to laboratory refinement, I feel certain, nevertheless, that the conclusions drawn are quite valid. All mention of amblyopia in this paper is limited strictly to amblyopia ex anopsia.

PRESENT THEORIES REGARDING AMBLYOPIA EX ANOPSIA

1. Because of constant suppression of vision in the affected eye, the retinal elements become nonfunctioning, much as muscle fiber degenerates from disuse. Without questioning further the pathologic process which should take place if this were true, one may place this theory in doubt by observing that actually there is no cessation of stimulation to the retinal elements. Light may reach them easily at all times (unless occluded by opacities), and it is to light that these

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elements respond. Again, there are many cases in which good acuity is restored almost immediately to eyes which have been occluded for prolonged periods. I refer to cases of high refractive errors and to cases of cataract, which have existed for many years in some instances. Surely, if prolonged disuse were a factor, amblyopia should result, a complication which usually does not occur. The theory of amblyopia resulting from disuse is not plausible.

2. Because of constant suppression of vision, the cortical centers adopt a habit of "not seeing." The retinal elements and pathways are thought to be intact, but the visual impressions received on the retina are not perceived, or, rather, are suppressed by cortical processes.

This may explain certain aspects of suppression or suspension of vision, but not amblyopia. Suppression phenomena are complete and are not subject to the gradations of acuity on the Snellen chart, such as are found with amblyopia.

FACTORS COMMONLY ASSOCIATED WITH AMBLYOPIA

In analyzing my series of cases, I tried to find those factors which appeared to have a bearing on the production of amblyopia. The following characteristics appeared with such frequency as to deserve mention.

1. Amblyopia was almost always monocular.

2. The refractive error was primarily hypermetropia, beyond the normal incidence of occurrence of hypermetropia. The hypermetropia was often of considerable amount, again beyond the incidence of occurrence of high hypermetropia. Only 2 cases of amblyopia with myopia were found.

3. When hypermetropia was found, it was almost always greater in amount in the amblyopic eye than in the good eye. This difference ranged from $+0.25$ to $+4.00$ D. It can be seen, then, that anisometropia occurred with unusual frequency.

4. Strabismus occurred in over 40 per cent of cases. The strabismus was chiefly convergent.

5. Finally, and most significant, the amblyopic eye was unable to fixate the object regarded, either monocularly or binocularly. The estimated true visual axis invariably failed to coincide with the object the patient was sure he was regarding.

PERTINENT PHYSIOLOGIC COMMENTS

Anatomically, the macular region differs from the rest of the retina in possessing a vast preponderance of cones. As the center of the macula is approached, the rods drop out completely and only cones are present. In the center of the macula is the fovea centralis, or central

pit, in which the cones are most closely packed, being thus the area of highest acuity, for visual acuity depends on the compactness of the retinal elements. As the fovea is left, visual acuity becomes progressively lessened as separation of the elements increases. Aubert and Foerster,[1] Dor[2] (1873) and Wertheim[3] (1894) investigated the relative acuity at various distances from the fovea in ordinary intensities of illumination. Wertheim derived a curve illustrating the variations in acuity from the fovea to the peripheral areas. This curve is not reproduced here, but an adaptation, in tabular form, of the findings from Aubert and Foerster is included.

Distance from Fovea	Angle of view	Acuity on the Snellen Chart
0° (fovea)	1′	20 / 20
2° 52′	5′	20 / 100
3° 13′	6′	20 / 120
3° 51′	7′	20 / 140
4° 17′	8′	20 / 160
7° 14′	12′	20 / 240
8° 32′	16′	20 / 320
10° 13′	19′	20 / 380
14° 37′	24′	20 / 480
16° 17′	45′	20 / 900
30° 20′	100′	20 /2000

It may be concluded from the data presented in this tabulation that at the center of the fovea visual acuity is at least 20/20 in the normal eye, and that as the distance from the fovea increases the acuity diminishes rapidly.

EVIDENCE IN SUPPORT OF NEW CONCEPT

It has been stated that the amblyopic eye does not use its true visual axis but, instead, uses a new visual axis, which falls outside the fovea. In so doing, the farther from the fovea the new axis falls, the less acute the vision.

The evidence is as follows:

1. At a convenient distance (1 meter), the patient fixes with the amblyopic eye (the other eye is occluded) an ophthalmoscope bulb. It will be apparent, on examination, that the corneal reflection of this bulb is eccentrically placed for such regard.

2. A second ophthalmoscope bulb of equal intensity, and at the same distance from the eye, is then alined so that its reflection on the cornea is so placed that it should coincide with the true visual axis. It will be found that the second bulb lies on the same spatial arc a certain distance of arc away from the first, the distance roughly depending on the degree of amblyopia.

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1. Aubert, H., and Foerster: Untersuchungen über den Raumsinn der Retina, Arch. f. Ophth. **3** (pt. 2):1-37, 1857.

2. Dor, H.: Beiträge zur Electrotherapie der Augenkrankheiters, Arch. f. Ophth. **19** (pt. 3):316-352, 1873.

3. Wertheim, T.: Ueber die indirekte Sehscharfe, Ztschr. f. Physiol. u. Physiol. d. Sinnesorg. **7**:172-187, 1894.

3. While he is fixing the first light bulb, the patient will be amazed to find, when questioned, that the second light (the one in the approximated true visual axis) is brighter and more easily seen. This is further evidence that the first visual axis in the preceding test is a false visual axis and is extrafoveal.

4. Now, while he is still fixing the first light bulb, the patient is asked to place his finger on it; to his surprise, he will find that as he fumbles for the first bulb his finger will unwittingly come much closer to the second. Apparently, the eye-hand coordination learned earlier in life has not changed and is still in sympathy with the true visual axis.

5. Mapping of a visual field will reveal that the plotted blindspot in the amblyopic eye does not correspond in position to that of a normal eye, but is displaced in a direction which coincides with the displacement of the visual axis, as predicted by the previous tests. (The visual field of an amblyopic eye is extremely difficult to take. The fixation of that eye is by no means as firm and steady as that of a normal eye, and the plotting, therefore, is rough and irregular. It is best accomplished by use of a stereocampimeter.)

6. Because the fixation of the amblyopic eye is uncertain and wavering, the visual acuity is not always the same but will easily vary a line on the Snellen chart, not only from day to day but even in the same examination. It is not at all uncommon for the patient to pick up an isolated letter here and there on Snellen lines much smaller than the one he is straining to read. With high degrees of amblyopia it will often happen that the patient says he can see the *E* when he looks at the door or other object alongside the chart.

7. By placing prisms of estimated values necessary to make the false and the true axis coincide, the examiner may often bring about momentary increased acuity. This effect is only transient, as the eye adjusts to the new condition and reassumes its false axis.

8. The final proof lies in the clinical results. If the treatment is directed to correcting the malprojection, progressive, rapid improvement takes place in a matter of weeks, instead of months or years. This is in sharp contrast to the simple occlusion treatment, which is based on the assumption that by forcing use of the amblyopic eye one will obtain return of vision.

9. As treatment is undertaken and vision improves, the aforedescribed processes are reversed, and it will be found that when normal vision is reached a normal visual axis relationship is also reached.

PROCEDURE IN TREATMENT

Simply stated, the general outline of treatment which is carried out consists in correcting the malprojection and once again restoring the true visual axis relationship of object to fovea. One is aided tremendously in this endeavor by a strong eye-hand coordination habit, learned very early in life. It is necessary to awaken the patient to consciousness of his malprojection and then, by use of corrective treatment which includes this habit of eye-hand coordination, allow him to restore or recapture proper visual alinement. Ideally, after he has obtained correct alinement, it is desirable to assure him of maintaining the correction. It is attempted, therefore, to give the patient, in addition to good vision, a pattern of binocularism by fusion and stereopsis. Unfortu-

nately, in actual practice this ideal is not easily obtainable. In many cases the patient after obtaining substantial visual improvement feels that he has accomplished his temporary goal and wishes to terminate treatment. For all this, there is still a large number of patients for whom binocular vision and stereopsis have not been obtainable in spite of arduous efforts on the part of the patient. The only recourse is to maintain the visual gain by constant treatment at home, supplemented with periodic rechecks at the office. At present, no other alternative is in sight.

It is to be understood that, as in all branches of medicine, treatment is to a certain extent individualized. The problem of keeping up interest, especially in younger children, requires patience and considerable ingenuity. It is painstaking work, requiring a great deal of personal supervision, even though a well trained office nurse can give invaluable assistance.

From the beginning of treatment the problem of malprojection of the visual axis is brought home to the patient, who must have an insight into his situation. We make him conscious of his malprojection by the very tests used in determination of his amblyopia. He cannot fail to be impressed as his puzzling ophthalmic condition is revealed to him, and he will often begin to read a line or two better almost immediately.

It is desired to have the patient appear at the office for treatments of one hour each day, or, failing this, two or three times a week as a minimum. Exercises to be performed at home are designed to produce correction of malprojection, in much the same manner as in the office. This is accomplished by exercises for eye-hand coordination such as tracing letters and pictures, various games of skill—darts, indoor horseshoe pitching, chess, checkers, chinese checkers—in fact, a multitude of devices in which the eye is used with the hand and interest intensity is high. The patient, given the idea of what is desired, will invent and suggest other interesting and helpful projects. He does all these tests monocularly, of course, and always with the realization of, and desire to correct, his malprojection.

In the office, vision is checked before and after each treatment. Home exercises are discussed, and difficulties are ironed out. A large white board on which are pasted vivid red disks of various sizes, from ¼ to 4 inches (0.6 to 10 cm.) in diameter, is presented to the patient as the initial exercise. With this he is given a box of thumb tacks, which he places one by one into the center of each disk while his unaffected eye is occluded. Malprojection becomes obvious. The tacks are invariably outside the disk, and always in the same position relative to the disk. Afterward, he is allowed to see his work, and then he tries again. We allow him to use both hands, and even to feel his way into the disk. He is relearning eye-hand coordination.

If the patient uses a flashing light instead of constant illumination while doing his exercises, it is found that the improvement is much more rapid. It appears that each time the light flashes off, and then on again, a new adjustment in projection must be made by the eye, thereby increasing the total number of stimulations. Such intermittent light can easily be arranged by plugging in an interceptor, which cuts the light off and on every few seconds.

From pinning the tacks on the board, the patient then advances into the copying of letters, which are printed on another board. He is given a pencil with which he points out each individual letter, one at a time, as he copies. The flashing light method is used here, too. The important feature in this exercise is not so much the copying of the letters as the adjustment in projection as the subject points with his sharp pencil before writing down the letter. Early it is observed that, while pointing at one letter he will, unwittingly, read the adjacent letter instead. He progresses to smaller and smaller letters. This is a valuable exercise, which at the same time requires the minimum of supervision.

As a rule, by the time acuity of 20/70 is obtained, exercises are begun for development of fusion. For a few minutes after each monocular treatment the patient is shown simple cards requiring simultaneous macular perception with the stereoscope, the rotoscope or any other instrument available, for it is not the instrument but the variety one uses in order to maintain interest. From then on, increasing time is spent on fusion and stereopsis; at the same time, visual acuity is being developed.

RESULTS

In summarizing the clinical results of the treatment of about 200 patients in this series, I shall divide them roughly into three groups according to the visual acuity recorded on initiation of treatment. These groups represent approximately equal numbers of patients, but it must not be inferred that amblyopia ex anopsia occurs in this ratio in the general population.

The first group presented initial vision of 20/200 or worse, amounting at times merely to appreciation of hand movements. Of this group, 60 per cent achieved vision of 20/50 or better, and about 5 per cent vision of 20/20. Of the second group, which presented 20/70 to 20/200 vision on admission, ultimately 85 per cent acquired vision of 20/30 or better, and 15 per cent achieved 20/20 vision. The third group, which presented initial vision of 20/60 or better, concluded their treatment with 70 per cent showing 20/20 vision.

Of all patients treated, about 30 per cent agreed to take further treatment for development of stereopsis. Of those who agreed, less than one half obtained the desired end result.

The average duration of treatment was approximately six weeks, with an average of three and one-half treatments per week.

Although age is a factor in success of treatment, it may safely be said that almost any age group can be treated successfully. In my particular series, the youngest patient was 4 years old and the oldest 41. In the same series, 52 per cent were between the ages of 5 and 15 years; 34 per cent were in the 16 to 25 year group, and 14 per cent were 26 years old or more. The majority of the adults treated were patients who sought improvement in vision in order to secure employment or pass an ophthalmic test for some other purpose. It was these patients in particular who wished to discontinue treatment as soon as their personal goal was reached. It was these patients, also, who were most anxious to secure some form of assurance as to their ultimate result in visual acuity.

ILLUSTRATIVE CASES

CASE 1.—This case is not unusual except for the patient's age. It illustrates that disuse is not a factor in production of amblyopia, that age is not an impossible handicap in overcoming amblyopia and that simple treatment with occlusion is not very successful.

Mrs. A. T., aged 41, was first seen on May 3, 1938, complaining of poor vision in her right eye, which had been present all her life. As a child, occlusion treatment of the good eye for a year failed to improve her vision. Examination revealed low hypermetropic astigmatism in her right eye, correction of which did not improve vision beyond a doubtful 20/400. No improvement was apparent with the pinhole test. Vision in the left eye was 20/20, uncorrected. The best estimation of muscle balance revealed 18 D. of exophoria in the right eye with 4 to 6 Δ base up; the blindspot of this eye as plotted on the stereocampimeter was enlarged and displaced slightly downward and considerably nasalward. The patient decided to take office treatments three times a week. The first treatment consisted in education regarding her malprojection. She was also instructed to place tacks into large red spots painted on a white board. At the end of the second treatment she had improved greatly at this exercise, and vision was 20/300. The third treatment consisted in the same treatment, with use of smaller red spots. She also began work with large letters under a flashing light. At the end of this treatment she read the 20/100 acuity line. At the end of the fourth treatment (or one and one-half weeks later), after she had worked on the chart under the flashing light, vision was 20/60. Fusion exercises were initiated, but she had no simultaneous macular perception. At the time of her ninth treatment she had second degree fusion and vision was 20/25—3. The blindspot had receded to almost its normal position. At this time circumstances prevented her continuing treatment.

In the main, this procedure is followed in all cases except as new ideas of minor importance are put into practice along the way. The following case reports are abbreviated for simplicity.

CASE 2.—This case is also cited because of the patient's age.

J. W., aged 4 years, was first seen at the age of 2½ years, when she presented a left convergent strabismus of ten days' duration. A correction for compound hypermetropic astigmatism was prescribed. Two years later, on May 9, 1938, the convergent strabismus was not evident except when no correction was worn.

The refractive error had not changed appreciably, but since the child knew her alphabet surprisingly well a good check on visual acuity was possible. Vision was 20/25 in the right eye and 20/70 in the left eye, with correction. She was given five treatments for amblyopia, after which vision in the left eye became 20/30. Fusion exercises were introduced. As far as could be determined, stereopsis was obtained, but she had no further improvement in acuity.

CASE 3.—This case illustrates rapid improvement in a patient whose original vision was extremely poor.

D. K., aged 10 years, presented vision of 20/20 in the right eye. With the left eye only hand movements at 3 feet (90 cm.) could be detected. On her first visit, on Dec. 4, 1937, she was hardly able to place tacks in a circle 3 inches (7.5 cm.) in diameter at a distance of 6 inches (15 cm.). Vision after the first exercise was 5/400. At the end of the fifth office visit it was 20/300. Visits, however, became very irregular, but at the end of the tenth treatment, on Feb. 12, 1938, she had 20/50 vision, at which time she was unable to continue.

CASE 4.—This case is an unusual instance of amblyopia with myopia.

M. B., aged 30, was seen on Jan. 29, 1940. Visual acuity in the right eye was 20/400, corrected with — 3.25 D. sph. to 20/100. Vision in the left eye was 20/200 corrected with — 1.50 D. sph. ⌒ — 50 D. cyl., axis 180 to 20/20. She made five office visits in February, after which vision in the left eye was 20/40. Five more treatments in March failed to improve vision further, although she acquired fairly good fusion, with no stereopsis.

CASE 5.—This case is of the type so frequently seen with hypermetropia, anisometropia and internal strabismus.

T. N., aged 7½ years, presented the chief complaint of internal squint since the age of 1 year. Visual acuity in the right eye was 20/25, corrected with + 2.75 D. sph. ⌒ + 1.00 D. cyl., axis 95 to 20/20. Visual acuity in the left eye was 20/400; correction with + 4.00 D. sph. ⌒ + 2.50 D. cyl., axis 90 gave no improvement. The estimated internal strabismus was about 30 degrees. Cooperation on the whole was rather poor, but after fifteen treatments, scattered over a period of three months, vision improved to 20/60 + in the left eye. There was no appreciable change in the strabismus.

The cases cited are not our "best" ones, but, rather, were picked at random to illustrate certain unusual factors. They indicate, too, the difficulties encountered in obtaining perfect cooperation with respect to office visits. On the whole, however, patient attendance was fairly satisfactory. Of course, the patients who made frequent, regular office visits benefited most in the shortest time.

COMMENT

In by far the majority of cases the amblyopia occurred in one eye only, in apparent agreement with all that is said about the assumption of dominance of one eye. In the cases in which amblyopia is present in both eyes, it is so much greater in one that the better eye can easily be said to be dominant. There are a few cases in which the amblyopia is almost the same in the two eyes. It is never great (rarely, 20/70). The amblyopia has always been found to occur with alternating strabismus.

Of the cases studied, a hypermetropia of 2.00 D. and over was present in over 60 per cent. Lesser degrees of hypermetropia were found in 24 per cent of the series. Predominantly hypermetropic astigmatism was present in 15 per cent, and myopia in 1 per cent. It is to be understood that an eye without astigmatism is rare, and that in classifying the cases according to the results of refraction, as previously indicated we have permitted ourselves considerable leeway, by assuming the larger component to be the chief refractive error. This, of course, is oversimplification, but it does not materially alter the general conclusions.

The hypermetropia not only was predominant, but was greater, with 3 or 4 exceptions, in the amblyopic eye. The difference varied from + 0.25 D. to as much as + 4.00 D. on occasion, but in the majority of cases was between + 0.25 and +1.00 D. The measurements were based on retinoscopic and subjective findings without cycloplegia. Since it is difficult to obtain accurate subjective data when amblyopia is present, any doubt as to the statistical results was settled by retinoscopic comparison. On application of homatropine the anisometropia decreased. The nonamblyopic eye then approached in plus acceptance the amblyopic eye. It was also noted that often as treatments progressed and vision improved the amblyopic eye had a tendency to lose plus acceptance and approach that of the good eye. This was not invariable, but occurred with such frequency that only a temporary correction was placed on the amblyopic eye until treatments were completed.

I have no explanation for these phenomena. Seemingly, the ciliary muscle loses a certain amount of tone under conditions of amblyopia. This is not as unphysiologic as it may at first appear. The progressive increase in plus acceptance by our patients at successive examinations at intervals of two or three years strongly indicates that the factor involved is a general loss of muscular tone reflected in the ciliary group. Be that as it may, no explanation will be attempted at this time.

It is to be emphasized that anisometropia in itself does not produce amblyopia. If it did, amblyopia would be found with myopic, astigmatic and hyperopic anisometropia, and in a ratio which does not conform with the facts. As a corollary, even hyperopic anisometropia is found with much greater frequency than amblyopia.

Clinical strabismus, chiefly convergent, occurred in association with amblyopia in about 40 per cent of cases. This is a striking frequency. Nevertheless, it may be said, from what has already been brought out, that the amblyopic eye by my definition possesses a subclinical squint. Surely, the relation of amblyopia ex anopsia and strabismus must be close. It certainly is not that of cause and effect. Amblyopia is found without strabismus and strabismus without amblyopia; moreover, the degree of one has no apparent effect on the degree of the other.

I cannot resist indulging in a bit of armchair philosophy. To me, the close association of these two entities means that they are at least parts of the same syndrome. This syndrome, however, originates in cortical processes, or in failure of the same. Binocular vision is undesirable; the nondominant eye deviates from its true visual axis only enough to destroy its existence; amblyopia ex anopsia results. Or, the deviation becomes excessive and strabismus results, in which case amblyopia may or may not be present.

If one does not postulate a cortical mechanism, how else can one explain the failures of surgical correction of strabismus? How often is it found after surgical overcorrection (recession or advancement or both) that the squint returns in a matter of days or weeks to almost the original degree? How often does one find that after a second operation the squint again returns in a short time? The problem is obviously one not of mechanics, but of mental aberration, a concept which explains why orthoptics in association with surgery is often of great help.

SUMMARY AND CONCLUSIONS

A new concept of the mechanism of amblyopia ex anopsia is presented, namely: (*a*) Amblyopia ex anopsia is poor vision due to malprojection of the affected eye so that the visual ray is directed eccentrically to the fovea. (*b*) The degree of amblyopia varies as does the deviation from the fovea.

In support of this concept is produced: (*a*) evidence of the deviation of the amblyopic eye as demonstrated by corneal reflections; (*b*) evidence of greater acuity when the true visual axis is approximated; (*c*) evidence that eye-hand coordination favors the original visual axis; (*d*) evidence of displacement of the blindspot as plotted on the visual field, a displacement which corresponds to the deviation demonstrated by corneal reflections; (*e*) evidence that improvement in vision is much more rapid and more certain if treatment is directed to correction of the malprojection, and evidence that as vision is improved by treatment the process of malprojection is reversed.

The procedure of treatment is outlined, with specific emphasis on the value of eye-hand coordination and of training devices which use intermittent illumination to increase the number of stimulations per treatment time.

The results are given in a few unusual cases.

The problem is discussed together with considerations of the possible relation of amblyopia ex anopsia to squint and the cause of squint.

In the light of what has been presented, I believe that the present definition of amblyopia should be reevaluated. In this paper, I have offered for consideration a new concept of the mechanism of amblyopia ex anopsia which appears more tenable.

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CONGENITAL IMPATENCY OF THE NASOLACRIMAL DUCT

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FROM a perusal of the literature, it would seem that congenital impatency of the nasolacrimal duct is a much rarer anomaly than our experience has led us to believe. In order to arrive at figures regarding the incidence of this condition and to learn the best method of treating it, the present study was undertaken.

Relatively few papers have appeared in the literature dealing with congenital impatency of the nasolacrimal duct, and almost without exception the condition has been described under the title of "congenital dacryocystitis." This term is a misnomer, since the underlying condition is not an inflammation of the lacrimal sac but, rather, an impatency of the nasolacrimal duct, the dacryocystitis occurring as a result of stasis. Another poor term appearing in the literature is congenital dacryostenosis, which implies simply a narrowing of the duct. This term should not be used, since it is not stenosis but, rather, a complete blockage which occurs. The only three papers which we have been able to find in the American and English literature suggesting a nomenclature at all compatible with the pathologic changes involved are those of Weeks,[1] Jackson,[2] and Zentmayer.[3] To our mind, the term congenital impatency conveys a much more accurate picture of the true pathologic process; in addition, it includes all cases in which both stasis and dacryocystitis occur, as well as those in which simply stasis without infection may exist. We suggest, therefore, that in the future this condition be known as congenital impatency of the nasolacrimal duct with or without dacryocystitis.

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Read before the Section on Ophthalmology at the Ninety-Sixth Annual Session of the American Medical Association, Atlantic City, N. J., June 13, 1947.

1. Weeks, J. E.: Congenital Occlusion of the Lachrymal Canal, J. A. M. A. **43**:1760 (Dec. 10) 1904.

2. Jackson, E.: Delayed Development of the Lacrimal-Nasal Duct, Ophth. Rec. **16**:321 (July) 1907.

3. Zentmayer, W.: Inperforation of the Lachrymonasal Duct in the New-Born, and Its Clinical Manifestations, J. A. M. A. **51**:188 (July 18) 1908.

Vlacovich,[4] in 1871, reported on 18 autopsies on newborn infants, in 4 of which he observed impatency of the nasolacrimal duct at the nasal end. It remained for Peters,[5] in 1891; Rochon-Duvigneaud,[6] in 1899, and Gunn,[7] in 1900, to recognize this congenital anomaly as the cause of epiphora, dacryocystitis and mucocele formation in the newborn. In an excellent article, Zentmayer,[8] in 1908, gave impatency of the nasolacrimal duct where this structure enters the inferior meatus as the commonest cause of congenital dacryocystitis; in addition, he cited 5 other causes of blockage of this canal, i. e., (1) delayed separation of the cells of the epithelial cord; (2) annular folds in the duct, such as those of Hasner; (3) faulty development of cartilages in this region; (4) pressure by the inferior turbinate bone, and (5) pressure on the bones of the face with forceps during delivery.

The only figures on the incidence of this condition which we have been able to find are those recorded by Stephenson,[8] who observed that 1.75 per cent of 1,538 children in the outpatient department of a children's hospital had a lacrimal obstruction present since birth, and by Kipp,[9] who maintained that 10 per cent of all cases of dacryocystitis occur in children under 1 year of age. In neither survey was any effort made to include those cases in which the condition cleared spontaneously.

For a proper understanding of congenital impatency of the nasolacrimal duct, a short discussion of the embryonic development is in order. The generally accepted concept is that the maxillary process in its development overlaps the paraxial region around the eye and thus leaves a fold of ectoderm buried between it and the lateral nasal process. This is the rudimentary nasolacrimal duct. At about the 35 mm. stage canalization of this rod of epithelial cells begins, owing to a disintegration of the cells of the central core. The process of canalization first begins in the inferior canaliculus, then proceeds to the superior canaliculus, then to the lacrimal sac and finally to the

4. Vlacovich, G. P.: Osservazioni anatomiche sulle vie lagrimali communicate all'Accademia di Scienze Lettere ed Arti in Padova nella seduta del 12 Marzo, 1871, cited by Schwalbe, G.: Anatomie des Auges, Jahresb. u. d. Leistung. d. Ophth. **2:** 63, 1871.

5. Peters, A.: Ueber die sogen. Thränensack-Blenorrhoe bei Neugeborenen, Klin. Monatsbl. f. Augenh. **39:**376, 1891.

6. Rochon-Duvigneaud, A.: Dilatation des voies lacrymales chez le fœtus et le nouveau-né consécutive à l'imperforation de leur orifice inférieur: Conditions anatomiques qui favorisent la dacryocystite congénitale, Arch. d'opht. **19:**81, 1899.

7. Gunn, D.: Lacrimal Obstruction in the Young, Ophth. Rev. **19:**31, 1900.

8. Stephenson, S.: A Preliminary Communication on Affections of the Tear-Passages in Newly Born Children, M. Press & Circ. **119:**103, 1899.

9. Kipp, C. J.: Dacryocystitis in Nursing Infants, T. Am. Ophth. Soc. **2:** 537, 1879.

nasolacrimal duct itself. The last portion to become patent is that of the puncta and the opening into the inferior meatus. The average age at which the lacrimal system finally becomes patent throughout is the eighth intrauterine month, and failure of the duct to become patent by the time tear formation begins, shortly after birth, gives rise to epiphora, dacryocystitis and mucocele formation.

The more recent, exhaustive studies of Fischer [10] on the formation of the nasolacrimal apparatus indicate that some of these concepts are in need of revision. According to him, and he has excellent evidence to support his claim, the nasolacrimal groove, or sulcus, forms alongside the line of fusion between the maxillary and the lateral nasal process, and the anlage of the nasolacrimal apparatus then develops beside this groove as a thickening of epithelium, which sinks into the embryonic connective tissue of this region. This ridgelike epithelial thickening then detaches itself from the surface epithelium and assumes a cordlike or rodlike form, broadened at the upper end. From this point his views as regards canalization are in close agreement with those generally accepted.

PRESENT STUDY

A series of 200 unselected, consecutive newborn infants at the Medical College of Virginia, Hospital Division, and St. Luke's Hospital was studied. The incidence of epiphora and dacryocystitis was noted, as well as the date on which symptoms of impatency disappeared. The only treatment employed was the local application of a penicillin ointment containing 1,000 Oxford units per gram of ointment base three times a day and daily massage by the mother over the region of the sac.

In 5 cases, not included in this series, in which probing had to be carried out, iodized oil U.S.P. was injected through the inferior punctum and roentgenograms were taken to learn at what level blockage had occurred. In 3 of the cases the impatency was unilateral, and in 2 cases both sides were affected.

In the series, 12 instances of congenital impatency, as manifested by epiphora and the presence of mucopus after pressure over the affected sac, were found. In 10 cases the epiphora appeared between the tenth and the twelfth day after birth, while in 2 cases tearing was delayed three and four weeks, respectively. Although mucopus could be expressed in every case, the employment of penicillin considerably reduced the amount of discharge, prevented conjunctival injection and completely eliminated incrustation of the lids. Symptoms disappeared

10. Fischer, F.: Die Entwicklung der ableitenden Tränenwege beim Menschen, Abhandlungen aus der Augenheilkunde und ihren Grenzgebieten, no. 22, Berlin. S. Karger, 1936.

in every instance without its being necessary to resort to probing, the longest interval being five months, the shortest three weeks and the average 2.3 months. One case, in which the patient did not return for follow-up study, though included in the series, is omitted from the statistical survey. In all but 2 cases the left side alone was involved, while in 1 case involvement was bilateral and in another only the right side was affected. We are unable to offer any explanation for the heavy dominance of involvement of the left side. All the infants with congenital impatency were term babies. A statistical summary of the series is given in the table.

Since the study of the original series was concluded, 5 cases have been observed in which the condition failed to clear up after conservative measures had been employed for six months. In these instances

Statistical Summary of Twelve Cases of Congenital Impatency of the Nasolacrimal Duct in Newborn Infants*

Case No.	Sex	Age at Onset of Epiphoria	Duration of Symptoms	Side Involved	Discharge on Pressure on Sac
1	M	12 days	5 mo.	Left	Gross
2	F	11 days	4 mo.	Left	Gross
3	F	4 weeks	3 mo.	Left	Gross
4	M	12 days	3 mo.	Left	Gross
5	M	10 days	2½ mo.	Left	Gross
6	M	11 days	2 mo.	Left	Gross
7	F	12 days	5 weeks	Both	Gross
8	F	3 weeks	1 mo.	Left	Gross
9	M	10 days	1 mo.	Left	Gross
10	M	10 days	3 weeks	Left	Gross
11	M	11 days	3 weeks	Right	Gross
12	M	.....	Not heard from	Left	Gross
Average (case 12 not included)		13.5 days	2.3 mo.		

* In all cases the impatency occurred in term babies. The incidence of congenital impatency in the entire series of 200 infants was 6 per cent.

we resorted to probing, and after such treatment the condition cleared immediately. This procedure was carried out, with the patient under ether anesthesia, after iodized oil had been injected through the inferior punctum and roentgenograms taken. In 2 cases involvement was bilateral, and in 3 cases only one side was affected. In every case the roentgenogram revealed a well filled sac, but no opaque material could be seen below in the duct. It might be concluded from this observation that in such cases the blockage is at the junction of the sac and the nasolacrimal duct, but we believe that, instead, the iodized oil has simply failed to enter the duct, which is either collapsed or filled with detritus. This belief is borne out by a simple experiment in hydraulics which we carried out.

A cellophane soda straw was cut the same length as that of the lacrimal sac and nasolacrimal duct and was occluded at each end. It was then filled to two-thirds capacity with colored water, and two small openings, 2 mm. apart, were made into the upper third of the tube.

Iodized oil was injected into the lower opening and the results were noted. Only the upper third filled, and the oil did not displace any of the water but regurgitated through the upper opening. From this experiment we have concluded that the presence of the oil in the sac only does not necessarily mean that the occlusion occurs at the level of junction of the sac and duct but, rather, indicates that the oil has failed to enter the duct.

In figure 1 the roentgenogram reveals well filled sacs in a case of bilateral impatency.

In all 5 cases probing was carried out with the No. 1 Bowman probe through the superior punctum and canaliculus, after the punctum

Fig. 1.—Anteroposterior roentgenogram, showing sacs well filled with iodized poppyseed oil, but none below this level.

was first dilated with the punctum dilator. We have found this much the simpler procedure, since the probe forms an acute angle with the longitudinal axis of the nasolacrimal duct and passes readily into the sac and duct with but slight upward rotation of the probe. The ease of this procedure is in sharp contrast to the difficulties encountered when the probe is passed through the inferior punctum and canaliculus, a procedure which necessitates an upward rotation of the probe of well over 90 degrees, resulting frequently in the creation of a false passage. The procedure is illustrated in figure 2.

In every instance, probing was carried out with extreme gentleness, the probe being allowed to find its own way, without forcing. When

the probe has reached the nasal floor, this being readily ascertained by the length of probe which has passed into the sac and duct, a submucous elevator is passed beneath the inferior turbinate process until the probe is encountered. At this time a sharp metallic click can be heard and felt. On rare occasions in which the duct is abnormally long or is redundant, the probe may enter the inferior meatus and still remain covered with mucous membrane. If the probe is felt to be covered with a cushioning layer of membrane, as detected with the submucous elevator, it should be vigorously rubbed with this instrument until the bare metal is encountered. The probe may then usually be seen, particularly if the inferior turbinate process has been shrunken with cotton pledgets steeped in epinephrine solution. After the probing has been carried out and patency established, the No. 1

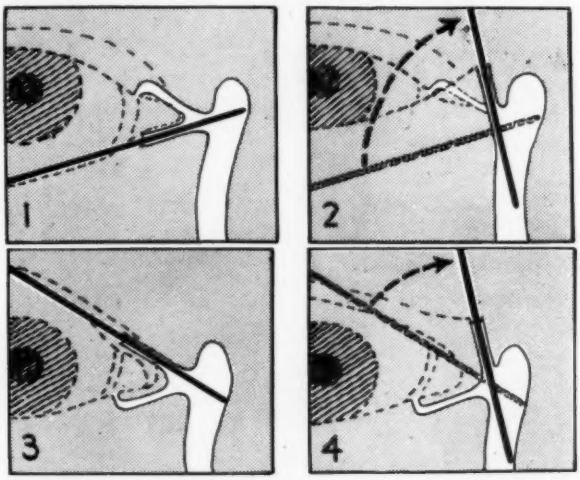


Fig. 2.—*1* and *2*, diagrammatic sketches, showing difficulty of probing through the inferior punctum and canaliculus, in contrast to *3* and *4*, illustrating the ease of probing through the superior canaliculus. *5* and *6* are artist's drawings of actual probing through the superior punctum and canaliculus.

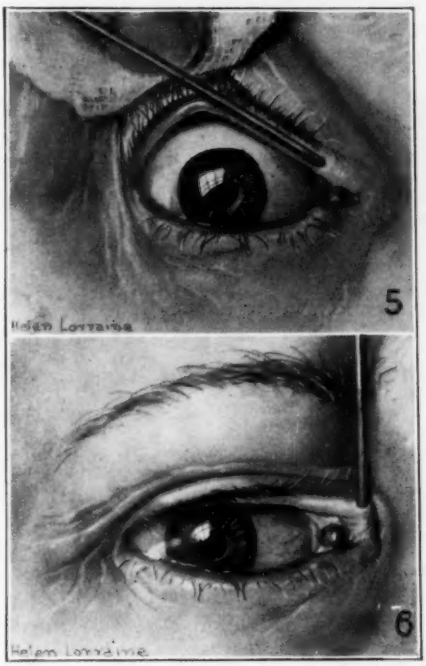
Bowman probe is passed through the inferior canaliculus in order to assure patency of that structure also. Figure 3 *A* and *B* show, respectively, posteroanterior and lateral roentgenographic views of the Bowman probe in place.

COMMENT

In a series of 200 consecutive, unselected newborn infants, 12, or 6 per cent, were found to have congenital impatency of the nasolacrimal duct. To ophthalmologists who see, for the most part, only cases in which the impatency has failed to clear up spontaneously, this figure will come as something of a surprise. Indeed, so high an incidence will no doubt surprise many pediatricians also, who are unfamiliar

with the picture of congenital impatency of the nasolacrimal duct and who dismiss cases of this anomaly as being instances of "stubborn conjunctivitis." At any rate, the condition is one of much greater frequency than is generally realized, and one in the treatment of which close cooperation of pediatrician and ophthalmologist pays off in good dividends.

In all our 12 cases cure was effected by the simple expedient of employing penicillin ointment and massaging the sac. This therapy is in accord with the teachings of Weeks,[1] Wood,[11] Peters,[5] Jackson [2] and Riser,[12] who advised conservative treatment for several months



before resorting to probing, and is at variance with the beliefs expressed by Cutler,[13] Gifford [14] and Mayou,[15] who advised early probing. From our observations, we are convinced that the more conservative measures,

11. Wood, C. A.: A System of Ophthalmic Operations, ed. 1, Chicago, Cleveland Press, 1911, vol. 2, p. 1592.

12. Riser, R. O.: Dacryostenosis in Children, Am. J. Ophth. **18**:1116, 1935.

13. Cutler, C. W.: Cases of Delayed Opening of the Naso-Lachrymal Septum in the Newborn, with Consequent Dacryocystitis, Arch. Ophth. **32**:289 (May) 1903.

14. Gifford, S. R.: A Hand-Book of Ocular Therapeutics, ed. 1, Philadelphia, Lea & Febiger, 1932, p. 223.

15. Mayou, M. S.: Lachrymal Abscess in the New-Born, Roy. London Ophth. Hosp. Rep. **17**:246, 1908.

followed by probing in the more recalcitrant cases (arbitrarily, those with duration of symptoms of over six months), offer the best method of treating this condition. This is particularly true now that one has the sulfonamide drugs and penicillin with which to control infection.

We are convinced that when probing must be carried out it should be done with the patient under general anesthesia, and not as an office procedure, as advocated by Goar.[16] Our reasons for this are threefold: 1. The infant can be kept absolutely still, so that gentle, unhurried probing can be carried out, thus greatly reducing the number of false passages made. 2. The annoyance of a crying infant, which distresses waiting parents, and other patients as well, is eliminated. 3. The inferior meatus can be explored and the probe located and freed from overlying membrane, if need be, a procedure which, as Berry,[17]

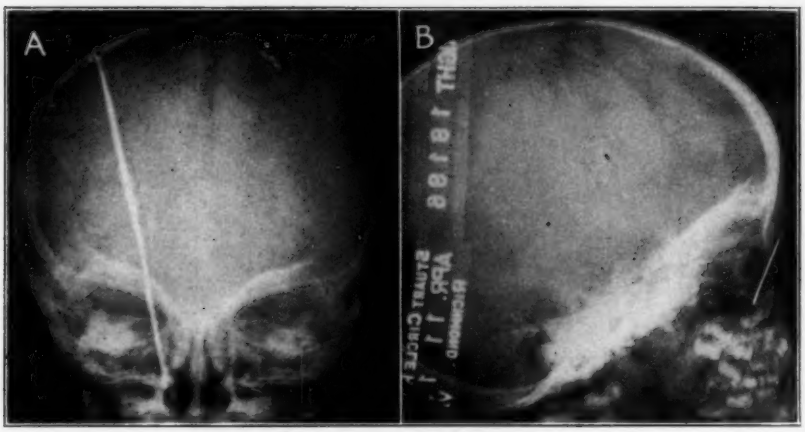


Fig. 3.—*A*, posteroanterior roentgenogram, showing the Bowman probe in place. The end extends into the inferior meatus.

B, lateral view, showing the Bowman probe in place. The angle at which probing must be carried out is well shown.

Woodruff,[18] Gunn[7] and, more recently, Larsson[19] have emphasized, is essential if success is to be assured.

In our hands, probing through the superior punctum has been found to be eminently satisfactory. When probing is carried out thus, the probe falls naturally into the sac and glides easily along the mesial wall into the duct. The ease of this maneuver is in contrast to the difficulties encountered when probing is carried out through the

16. Goar, E. L.: Infantile Dacryostenosis, M. Rec. & Ann. **37**:611, 1942.

17. Berry, J. C.: Treatment of Obstruction of the Lachrymal Duct, Boston M. & S. J. **160**:541, 1909.

18. Woodruff, H. W.: Congenital Dacryocystitis, Illinois M. J. **60**:380, 1931.

19. Larsson, S.: Treatment of Congenital Atresia of the Nasolacrimal Duct, Acta ophth. **16**:271, 1938.

inferior punctum, a procedure in which the entering probe runs head on into the mesial wall and, to enter the duct, must be rotated through a wide angle, a maneuver in which it is easy to force a false passage. Gifford [14] advocated passage of the probe through the superior punctum and canaliculus, but he first split the canaliculus and then introduced a No. 5 Bowman probe. We feel that this procedure is unduly traumatizing, and in our hands all that has been necessary is simple dilation of the punctum, followed by introduction of the smallest Bowman probe.

SUMMARY

The term "congenital impatency of the nasolacrimal duct," instead of the terms "congenital dacryocystitis" and "congenital dacryostenosis," should be used. In a series of 200 consecutive, unselected newborn infants, 12 cases of congenital impatency of the nasolacrimal duct were found, an incidence of 6 per cent. In all cases the condition cleared under conservative measures, consisting of daily massage of the lacrimal sac and local application of penicillin ointment. All the infants were term babies.

In cases, not included in the series, in which probing was resorted to (after six months of conservative treatment), the No. 1 Bowman probe was introduced through the superior punctum and canaliculus after dilation of the punctum with the dilator, with the patient under ether anesthesia. The inferior meatus was explored with a submucous elevator and the probe located and rubbed until bare metal was felt. Cure was effected in all instances.

Injections of iodized oil U.S.P. through the inferior punctum revealed well filled sacs but no radiopaque material in the duct, an observation which was due probably not to a blockage at this level but, rather, to failure of the material to enter the duct.

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ABSTRACT OF DISCUSSION

DR. J. V. CASSADY, South Bend, Ind.: The authors advise conservative treatment of dacryocystitis in infancy. They believe that the nasolacrimal duct should not be probed until every device has been used to clear up the infection by conservative treatment. I recently reviewed the literature and reported a series of cases in which I probed the duct early. I concluded that prolonged conservative treatment may be more harmful than prompt opening of the obstructed duct.

One should concur with their use of the term congenital impatency of the nasolacrimal duct, which indicates the etiologic factor in the dacryocystitis. As the authors point out, the condition is neither congenital dacryocystitis nor congenital dacryostenosis. In other words,

almost all dacryocystitis of infancy follows atresia of the duct because this structure has failed to open at birth.

As they have pointed out, in a large number of newborn infants the nasolacrimal duct is not patent. Schwartz (*Ber. ü. d. Versamml. d. deutsch. ophth. Gesellsch.* **50:** 30-35, 1934; Congenital Atresia of the Nasolacrimal Canal. ARCH. OPHTH. **13:** 301 [Feb.] 1935) found the ostiums closed in 35 per cent of late fetuses, while Dr. J. Parsons Schaeffer, in a personal communication, said:

> This report that the ostiums of the nasolacrimal duct were closed in 35 per cent of fetuses during the last few months of pregnancy is, I believe, a conservative statement. . . . I have occasionally noted complete absence of the nasolacrimal membranes during the seventh and eighth fetal months, but it is much more typical to find such membranes present at and shortly after birth.

Many lacrimonasal membranes rupture spontaneously at or soon after birth, before tears form and symptoms of dacryocystitis appear. Dacryocystitis in newborn infants is rare during their stay in the hospital; in a survey of 1,000 newborn babies, only 1 case was found within the first week after birth.

If dacryocystitis appears, it will not be cured until the obstructing membrane is ruptured. In the authors' first cases, spontaneous resolution of the infection occurred after several months of conservative treatment, but in their later cases, in spite of six months of conservative treatment, patency did not occur until they probed the duct. I have had prompt subsidence of symptoms in a large number of infants by sounding the duct early. The probing was done as an office procedure, with local anesthesia, without injury to the lacrimal passages. The authors believe that conservative measures, followed by probing in the more recalcitrant cases (arbitrarily those with duration of symptoms over six months), offer the best method of treating this condition. Conservative treatment for one or two months should be sufficient to ascertain whether the atresia of the duct will clear up spontaneously. Considering that cure can be effected so easily with a single sounding of the duct, I believe this measure should be carried out.

The authors advocate using the upper punctum and canaliculus if it is necessary to probe the duct. I have usually used the lower one, and in 100 cases I have seen no untoward effects or damage to the lacrimal passages. I have used the upper punctum and canaliculus in only a few instances. Their argument and the drawings illustrating it seem logical.

DR. JOHN H. DUNNINGTON, New York: The authors have correctly termed this condition congenital impatency of the nasolacrimal duct, for, as they have pointed out, it is not a stenosis of the duct and the dacryocystitis is a sequela of the impatency. Their finding of 12 cases of congenital impatency in a series of 200 consecutive newborn infants is both interesting and surprising. This condition is more frequent than is generally realized, for the average ophthalmologist sees only cases in which spontaneous canalization does not occur. I am in entire accord with the authors' desire to withhold instrumentation, and I believe, as they do, that in most cases the obstruction will respond

to expression. The percentage of cures by expression will increase greatly if one adheres to a technic described by Crigler (Crigler, Lewis: Treatment of Congenital Dacryocystitis, J. A. M. A. **81:23** [July 7] 1923).

1. The tear sac is allowed to become fully distended. We caution the mother not to wipe the eye or in any way to press on the tear sac before coming to the clinic or office. She is given a 25 per cent solution of protargin mild (argyrol) or other antiseptic eye lotion, to be dropped into the culdesac three times a day, to protect the eyeball from infection.

2. The infant's head is held between the surgeon's knees in a manner similar to the method in vogue of inspecting the eyeball. Assuming that it is the right sac that is affected, he places his right thumb over the sac in a way to shut off the return flow through the puncta. This is done by holding the thumb sidewise, with the thumb nail outward and forming an acute angle with the plane of the iris. The edge of the thumb is now pressed downward over the puncta, compressing it against the rim of the orbit; with this point of pressure maintained, the thumb is rotated to the right, at the same time pressing downward, abruptly, over the sac. The fluid, now being compressed by the thumb, transmits the pressure to the walls of the sac, which must give way at its weakest point, which happens to be the site of the nasal opening.

If care is taken that the thumb is applied in such a way as to prevent regurgitation into the conjunctival sac and sudden pressure is exerted over the distended lacrimal sac, the retained fluid will frequently burst the persistent fetal membrane at the lower end of the nasal duct. Crigler reported that he had had no failures after seven years' use of this procedure. In my hands it has not been uniformly successful, but has produced a cure in so many instances that I can heartily recommend its trial.

There is general agreement that probing should be carried out when conservative measures fail, and I agree with Dr. Guerry and Dr. Kendig on the advisability of performing it with the patient under general anesthesia. Although I have always followed the conventional technic of entering the sac through the inferior punctum and canaliculus, I see no objection to the method described here, unless it be to the use of such a small probe. I believe in the maxim, "The smaller the probe the greater the chance of creating a false passage"; so I uniformly introduce a no. 3 probe into the duct.

Prof. Dr. Raul Argañaraz, Buenos Aires, Argentine: I shall try to explain why massage and probing are successful in curing dacryocystitis in nearly all newborn children, and why the same treatment applied to adults with the same malady has failed in nearly 90 per cent of cases.

The cause lies in the anatomic and pathologic structures, which are entirely different in the newborn infant and in the adult. In the case of the newborn infant the closure of the inferior opening of the nasolacrimal duct results in wide dilatation of the entire sac and bony structure, while in the adult the growth of inflammatory fibrous tissue blocks the nasolacrimal duct for its entire length.

Dr. Everett L. Goar, Houston, Texas: I agree with the authors that it is good therapy to treat this anomaly conservatively, but conservatism can be carried too far. In any case in which the duration of impatency of the lacrimal duct goes beyond a few months a stricture is likely to form that is hard to relieve. It is a simple matter to stretch the lower punctum with a sharp-pointed punctum dilator and to slip a no. 1 or no. 2 Bowman probe into the nose. It is unnecessary to give the baby a general anesthesia. The hardest part of this procedure is to hold the baby's head still between the knees, at the same time everting the lower lid to expose the punctum. A well trained assistant is necessary. Usually one probing is enough. There is, therefore, no reason for wasting valuable time in applying hydrostatic pressure over a long period.

Dr. DuPont Guerry III, Richmond, Va.: Dr. Kendig, who is a pediatrician, will express the pediatrician's point of view.

Dr. Edwin L. Kendig Jr., Richmond, Va.: As a pediatrician, I wish to stress three points. First, congenital impatency of the nasolacrimal duct is of common occurrence, as shown in the figures Dr. Guerry and I have presented; second, conservative treatment is effective in the vast majority of cases, and, third, six months seems to be an adequate period of trial of conservative therapy.

Two of the discussers have expressed the belief that probing should be done early; but several pediatricians with whom we discussed the paper and the matter beforehand stated their opinion that conservative therapy should be given a trial even longer than six months, and no pediatrician consulted was willing to have probing done before the age of 6 months.

SPONTANEOUS ABSORPTION OF CONGENITAL CATARACT FOLLOWING MATERNAL RUBELLA

LEON H. EHRLICH, M.D.
NEW YORK

THE OCCURRENCE of cataract and other congenital defects in infants born to mothers who had rubella during the early part of the gestation period has become well known in the few years since 1942, when Gregg [1] first noted the connection in Australia and Reese [2] published the original American report two years later. Although various other ocular defects, especially microphthalmos, nystagmus and glaucoma, have been frequently noted, little attention has been paid to another, most interesting finding in a few of the eyes.

Some of these cataracts have been needled, but, surprisingly, only a thin membrane was found, dividing readily as a result of the instrumentation originally intended solely to open the anterior capsule and expose the lens fibers to the action of the aqueous.

Gamble [3] was the first to report such a membranous cataract. In 1945 he described the case of a baby girl who when first seen at the age of 6 months had in each eye a membrane with a dense central area and a less dense peripheral area, through which a faint red reflex could be seen. The lens of the right eye required needling three times, as the membranous cataract proved to be "rubbery" and moved with the knife, making it difficult to achieve an incision. The last operation on this eye was performed with use of two Ziegler knives at the same time, a procedure which proved to be more effective than the use of one knife only. The membrane of the left eye was successfully needled on the first attempt. In passing, it is noteworthy that this child was born in 1935, before the current decade, in which the connection between congenital anomalies and rubella during pregnancy was appreciated and which has provided all other recorded cases.

From the service of Dr. Edward Bellamy Gresser at the Beth Israel Hospital.
Read at a meeting of the New York Society for Clinical Ophthalmology, Feb. 3, 1947.

1. Gregg, N. M.: Congenital Cataract Following German Measles in Mother, Tr. Ophth. Soc. Australia **3**:35, 1941.

2. Reese, A. B.: Congenital Cataract and Other Anomalies Following German Measles in the Mother, Am. J. Ophth. **27**:483 (May) 1944.

3. Gamble, R. C.: Membranous Cataract Due to Rubella in the Mother, Am. J. Ophth. **29**:737 (June) 1946.

Long and Danielson [4] presented a series of which case 3 was the first of the cases of membranous cataract to be published, although Gamble's case had been presented at a meeting a few months earlier. This case was that of a male infant, born at term, in whom bilateral cataracts were observed shortly after birth. The entire pupillary area of each eye was opaque. At the age of 6 weeks, a discission was performed on the right lens, but a clear pupil was not obtained. Seven months later, when a similar procedure was performed on the other eye, a vertical incision made through "a soft membranous" cataract resulted in the immediate appearance of a clear opening.

The third such case was described by Blake.[5] In 1944 he saw a 2 month old baby with small eyeballs, alternating esotropia and roving nystagmus. On dilation of the pupil, the lenses showed a white, asbestos-like opacity, with no clear cortex. The mother stated that she had had rubella during the second month of her pregnancy. Bilateral discissions were performed six months later. When the knife needle was drawn across the capsule, the membrane divided readily, leaving a clear, black pupil at once. No soft lens matter was present, and there was practically no reaction after the operations.

A similar case, in which, however, no history of rubella could be elicited, was presented by Jeancon.[6] When the discission was performed, only an empty capsule was found, which opened without any cortex being evident. There was practically no postoperative reaction. Eleven months later the left eye was operated on, with a similar satisfactory result.

REPORT OF A CASE

B. S., a white girl, was born on Nov. 16, 1943, at Woman's Hospital, New York. The obstetrician (Dr. G. Gordon Bemis) stated that the delivery was a prophylactic one with low forceps; the birth was four weeks premature, and the infant weighed 4 pounds 2 ounces (1,870 Gm.). Except for rubella during the first month, the pregnancy was entirely uncomplicated. Shortly after birth it was noted that the baby had what appeared to be congenital cataracts. When she was examined a few days later, dense white cataracts were seen, although incomplete pupillary dilation prevented study of the periphery of the lens. The pupils reacted to light. The eyes were of normal size, and the anterior chambers were shallow. The corneas were clear. The ocular tension seemed normal on palpation. No other congenital defects were found by the pediatrician.

At the next examination, on May 12, 1944, no change in the appearance of the cataracts was noted. Four months later the opacification of the right lens

4. Long, J. C., and Danielson, R. W.: Cataracts and Other Congenital Defects in Infants Following Rubella in the Mother, Arch. Ophth. **34**:24 (July) 1945.

5. Blake, E. M.: Congenital Membranous Cataract, Am. J. Ophth. **29**:464 (April) 1946.

6. Jeancon, E. C.: Congenital Cataracts in Children, Am. J. Ophth. **28**:904 (Aug.) 1945.

was observed to be definitely less dense, and a red fundus reflex could be seen through the thinner portions of the membrane. After another three months the lens showed similar clearing and gave the impression of undergoing absorption. With the passage of time, the clearing process in the lenses slowly, but gradually, progressed. Alternating esotropia and nystagmus developed. The child had sufficient vision to walk about safely and to recognize large objects. She had been found to be deaf.

Despite the presence of some useful vision and the apparent continuation of the clearing process in the lenses, it was decided to perform discissions so as to provide the best possible sight to enable the child to attend a school for the deaf. Accordingly, in November 1946, Dr. Edward B. Gresser needled the right lens, which promptly and easily divided, presenting a black pupil and no evidence of any lens substance. Because of the ease of the procedure, the left lens was operated on while the child was still under the anesthesia. This time the membrane did not divide, but tore loose from its attachments and rolled up to form a small ball in the anterior chamber. There was no reaction in either eye the next day. After one week the right eye showed the same satisfactory pupillary opening, but the free membrane in the left had unrolled and attached itself to the anterior surface of the iris, covering the pupil. This eye has not yet had a second operation, which is now indicated. The parents report that the child shows obvious and pronounced improvement in vision since the operation.

COMMENT

There can be no doubt that definite lenses were present at birth in this infant and that these lenses subsequently were absorbed. The reports of the other cases previously mentioned were analyzed to learn whether such absorption also may have occurred.

Jeancon [6] stated that the parents of the infant she reported observed that the white masses in the pupillary areas were much more intensely white shortly after birth than at the first examination, a year later. At that time a fair red reflex could be seen, and three days later the right eye was operated on. When the child was seen again, after a year's interval, the capsular opacity appeared as dense as at the first examination, but there was a better red reflex, which led the author to conclude that further absorption of cortex had taken place.

Gamble [7] saw his patient first in March 1936, when she was 6 months old, and he stated the belief that the lenses had more thickness at that time than later. The right lens had snowflake-like opacities, and the left lens was diffusely opaque; the peripheral areas were less opaque than the center. By 1939 the lenses appeared to be membranous with a dense central area. The first needling, in 1940, on the right eye showed that the lens was semimembranous with some cortical material liberated by the operation. The first needling on the left eye, in 1943, showed the lens to be definitely membranous with no cortical material.

When the possibility of spontaneous absorption of the lens was considered in the previously described case from the series of Long and

7. Personal communication to the author.

Danielson, Dr. Long [7] wrote that the needling was performed on the right eye when the child was about 8 weeks old, at which time a definite lens seemed to be present, and not a membrane, although the inability to dilate the pupil widely may have made the examination misleading. That a thin membranous cataract was observed at operation on the left eye, performed seven months later, Dr. Long considered suggestive of some absorption of the lens substance with the passage of time.

The difference in the condition of the lens operated on second in each of the 3 cases just discussed supports the belief that there was at least some loss of lens substance in the interval following the first operation. In no case was there such a definite and observable change as took place in both eyes in the case reported here, but the process appears similar. The mechanism of the absorption of the lens material is open to speculation. Jeancon assumed that her patient had morgagnian cataracts in which complete absorption took place. Such an explanation does not apply to the present case, as no liquefaction was seen, but it is possible that there occurred small, even microscopic, areas of liquefaction from which absorption took place too rapidly after their formation to permit them to achieve grossly observable dimensions. Microscopic study by Swan [8] of the lenses of 3 infants who died of congenital defects following maternal rubella during pregnancy showed massive necrosis in the lenses of 2, with vacuolation. Absorption of the fluid from such vacuoles with constant development of new vacuoles, which were absorbed in turn, would result in a gradually thinning cataract and ultimate membranous transformation.

Duke-Elder [9] stated that congenital total cataract represents a general opacity of all the lens fibers, which, presumably, is the result of a severe disturbance acting throughout the entire period of development. In some cases the lens may shrink, forming a membranous cataract and producing the condition of pseudoaphakia. The shrinkage of the lens results in a deep anterior chamber and a tremulous iris; and the pupillary area is occupied by remnants of the capsule, which may show considerable epithelial proliferation. Duke-Elder did not make clear whether this formation of membranous cataract occurs after birth or prior to it, resulting in the latter event in a congenital membranous cataract. Admittedly, this is not especially important, as the moment of birth is an incident of no great developmental significance in the life cycle of the lens, in particular of this type of cataract.

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8. Swan, C.: A Study of Three Infants Dying from Congenital Defects Following Maternal Rubella in the Early Stages of Pregnancy, J. Path. & Bact. **56**:289 (July) 1944.

9. Duke-Elder, W. S.: Text-Book of Ophthalmology, St. Louis, C. V. Mosby Company, 1938, vol. 2, p. 1373.

Membranous cataract and its development from congenital cataract have been recognized for many years, but the subject apparently is unfamiliar to many ophthalmologists. All that Duke-Elder has to say on the matter has already been presented, and the comprehensive texts of Berens and Bellows make no mention of it whatever. The absorption of the lens material from cataracts in children was briefly mentioned by Fuchs [10] ; but, interestingly, the best description of the condition that I have seen was published one hundred and thirty-eight years ago. The following quotation from Saunders'[11] treatise on diseases of the eye is of clinical, as well as historical, interest:

> The efforts of nature in disease are seldom stationary, and even when they fail to accomplish the cure, the correctness of the intention may be clearly discerned: thus in the congenital cataract, after the crystalline lens is converted into an opake substance, it is gradually absorbed; and in proportion to the progress of the absorption, the anterior lamella of the capsule retires upon the posterior until they form one membrane which is white opake and very elastic. This is the conversion of the lenticular into the capsular cataract: all that is capable of being absorbed, nature herself removes, and she only fails to accomplish her purpose, because the capsule cannot be destroyed by this process.

This description applies obviously to the condition reported here, even to the ultimate necessity of performing discissions because of the partial obstruction to sight. The observation that the membrane is very elastic confirms the difficulty that Gamble had in dividing the membranous cataract in his case.

SUMMARY

A hitherto unreported development in congenital cataract following maternal rubella is its spontaneous absorption, leaving only a membrane in its wake. Such an absorption has rarely been seen in congenital cataracts of presumably other origins. A case in which the process occurred is described. Four other cases in which this process may have taken place, in three of which the mother had rubella during the early part of the pregnancy, are cited.

211 Central Park West (24).

10. Fuchs, E.: Text-Book of Ophthalmology, translated by A. Duane, ed. 7, Philadelphia, J. B. Lippincott Company, 1924, p. 635.

11. Saunders, J. C.: A Treatise on Some Practical Points Relating to the Disease of the Eye, London, Longman [and others], 1811, p. 132.

DISTANCE. DISCRIMINATION

I. Theoretic Considerations

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THE EXPERIMENTAL technics and psychophysical methods utilized in the testing of binocular distance discrimination are not new developments; many features are to be found in standard texts. The present exposition is an attempt at a closer integration of certain elements of physiology with those of psychophysical methods, by which it is believed that greater significance may be obtained for both. A brief statement of the problem will first be made, and then those points significantly affected by the present outlook or procedure will be expanded.

The customary method of measuring distance discrimination is to present two objects, such as vertical rods, which may be made to differ in distance from the observer. These are seen through an aperture in a screen, thereby excluding certain cues. Nevertheless, the exclusion of cues other than retinal disparity or binocular parallax is by no means as complete as is often imagined; the size cue, for example, is seldom eliminated. For the present, however, only retinal disparity will be considered.

Retinal disparity is the difference between the retinal images, consequent on the lateral separation of the eyes. If great enough, these image differences are interpreted as differences of distance. The linear displacement of one test object with respect to the other may be converted to an angular difference of separation of the retinal images, and it is in this form that the threshold of distance discrimination is commonly presented.[1] As in all such cases, the threshold must rest on a statistical basis.

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1. Duke-Elder, W. S.: Text-Book of Ophthalmology, St. Louis, C. V. Mosby Company, 1940, vol. 1, p. 1077.

When more than two rods are used, they may be arranged so as to appear at the same distance as the object being fixated; the locus of such apparently equidistant points constitutes one form of the horopter. An analysis of the relations of the retinal images of objects so arranged furnishes the basis for the concepts of corresponding and noncorresponding areas—important elements in the theory of binocular vision.

The discrimination of distance may be tested in the manner previously described or by the stereoscope, which presents two pictures the retinal images of which differ in the same way as do the images of the test objects just discussed.

By one of several statistical methods, the judgments obtained in the test are made to yield a threshold. The physiologic and psychophysical principles involved deserve careful consideration, for two reasons: (*a*) A valid comparison of thresholds requires either that all conditions be the same or that these conditions be specified and that the effect of variations therein be known; (*b*) analysis shows that the threshold data contain information on two physiologic aspects of distance discrimination which have not hitherto been properly distinguished and evaluated.

With this outline in mind, further discussion will be devoted to an elaboration of points considered new or necessary to the total argument.

I. GEOMETRIC AND STATISTICAL ASPECTS OF THRESHOLD OF DISTANCE DISCRIMINATION

The relationships involved in binocular parallax are diagrammed in figure 1. The eyes are looking at A, and M and N are the nodal points of the left and right eyes, respectively. The retinal images of A are a_l and a_r; and since A is being fixated, these fall on the two foveas. A second object, B, may be moved along a line BN, parallel to AM; five positions are indicated by the subscripts *1* to *5*. B will form an image on the temporal portion of the retina of the left eye and on the nasal portion of the retina of the right eye. Regardless of the position of B, its image on the right retina will be at b_r. On the left retina, however, depending on the position of B, its image will be at b_1, b_2, . . . b_5.

When A is fixated, there will be a position of B which will be judged equidistant; this will be at or near B_3. The exceptions are important but will be considered later. At B_3 the visual angle separating B_3 from A will be the same in the two eyes ($< b_rNa_r = < b_3Ma_l$); the images of B_3, lying at the same distance and in the same direction from the foveas, will be fused, and B_3 will appear as a single object on the right of, and at the same distance as, A. When the second object is at some much greater distance, as at B_1, the angle b_1Ma_l is smaller than angle b_rNa_r, and when it is much nearer, as at B_5, the angle b_5Ma_l is greater than angle b_rNa_r; if these differences of angle are sufficient,

the observer will report seeing A, the object fixated, as single and B as double. Certain other positions, B_2 and B_4, for example, which lie closer to B_3 and give angles differing from b_rNa_r, but to a lesser degree than in the previous case, will lead to reports of B as single and farther or nearer than A. Slight differences will thus lead to fusion and the perception of a third dimension; greater differences will lead to diplopia; both may be considered as differing degrees of retinal disparity.

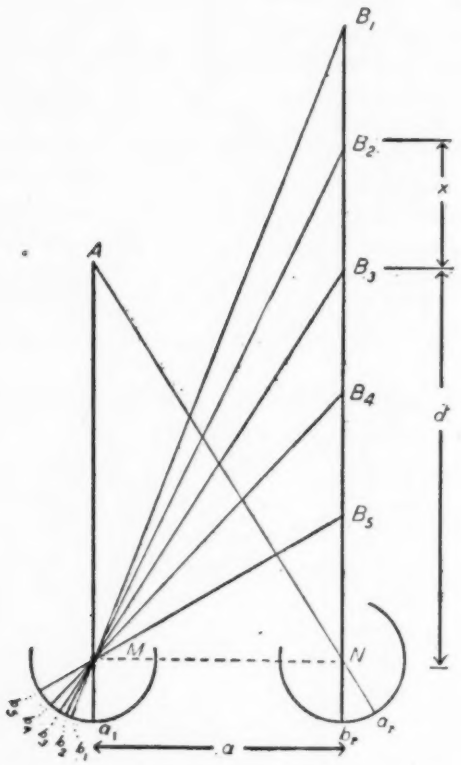

Fig. 1.—Relations involved in binocular parallax.

Certain other angular relations may now be mentioned. The parallactic angle of B with relation to the two eyes is angle NBM and that of object A, NAM. Depending on the position of B, its parallactic angle will be smaller than, equal to or larger than that of A. The customary threshold of distance discrimination is the difference between the parallactic angles of A and B when B is judged to be just noticeably nearer or farther than A; this angle is commonly designated by the Greek letter eta (η). It must be remembered that the diagram is not to scale: the interpupillary distance, NM, is approximately 6.5 cm., and

the distance of A and B from the eye, about one hundred times as great. The separation of the targets is about that of the eyes, but may be greater or less in the amounts actually employed in the present experimental work without invalidating the relations considered in the following discussion.

As diagrammed, the parallactic angle of A, NAM, is equal to the visual angle separating A and B for the right eye, a_rNb_r, while the parallactic angle of B, or NBM, is equal to the visual angle separating A and any position of B as seen by the left eye, a_lMb. The formula for the difference in binocular parallax of two objects, or binocular disparity (η), may be derived as follows: Assume a to be the interpupillary distance and d the distance from the nodal points to the fixed object A. If B is perceived to be "just noticeably far" at B_2, then the linear threshold is expressed by the equation

$$B_3 - B_2 = x$$

The parallactic angle of A is NAM, and its tangent is $\frac{a}{d}$; the parallactic angle of B is NB_2M, and its tangent is $\frac{a}{d+x}$. Since the angles are very small (of the order of 1/100 radian), the tangents may be taken as the measure of the angles in radians. Since η is the difference between the two parallactic angles,

$$\eta = \sphericalangle NAM - \sphericalangle NB_2M = \frac{a}{d} - \frac{a}{d+x} = \frac{ax}{d^2 + dx}$$

and since d is very large as compared with x, the denominator may be considered as d^2 without appreciable error. The formula thus becomes

$$\eta = \frac{ax}{d^2}$$

where a is the interpupillary distance; x, the linear threshold, and d, the distance of the targets from the observer.

Because of the relations pointed out between the parallactic angles of the objects and the visual angles of the separation of the objects, η is a measure of the difference between the parallactic angles. Obviously, the smaller the linear threshold x, the smaller will be its transformation, η.

The distance x has so far been treated as a single fixed distance, but, as in the case of other thresholds, it (or its transformation, η) is a statistical constant, a point that has often been lost sight of in calculating or comparing measures of binocular distance discrimination.

The linear threshold of distance discrimination has, like other thresholds, been variously defined; it is clear that it must be either a rough approximation or a statistically obtained value. To emphasize the statistical nature, imagine, for example, that ten or one hundred reports are obtained for various positions of the movable rod along the line B_1—B_5. With the rod at position B_3 the reports would all be "single," and probably all "equidistant." As the rod receded toward B_2, although the reports would still be "single," those of "far" would

begin to appear, and the number of "equal" reports would decrease until with the rod at B_2 all reports would be "single" and "far." As the rod continued toward B_1, the reports of "far" would continue and those of "double" would appear and increase until with the rod at B_1 all reports would be "far" and "double."

The divisions into five categories ("double," "single," "near," "far" and "equal") would hardly be useful in any practical situation, but it is introduced to illustrate the importance of instructions to the observer and the possible perceptions that occur in distance discrimination. Thus, in one experiment in this laboratory the instructions for the setting of the movable rod were "equal," "just noticeably far" and "just noticeably near." The distributions about these points (B_3, B_2 and B_4 of figure 1) were such that no overlapping took place; thus, there were positions which were too far to be called "equal" and not far enough to be called "far." These facts are not unknown in psychophysics but have often been overlooked in the study of distance discrimination, and for this reason they deserve reemphasis.

The case of two points may now be extended to a series, for example, the five points, *B*, *C*, *A*, *D* and *E*, of figure 2, lying in the horizontal plane which passes through the nodal points of the two eyes, the so-called horizontal horopter. The objects and the two nodal points are diagramed as lying on the circumference of a circle; the angles *MAN*, *MBN*, and so on, will be recognized as equal because all intercept the same arc, *MN*. This is the Vieth-Müller circle, or horopter. The diagram is geometrically correct but two difficulties are encountered in its practical application, one statistical and the other physiologic.

In the first place, the points are determined by certain statistical and subjective criteria. Aguilonius,[2] who introduced the concept, thought of the horopter as "the sum of all points seen single while the point of sight remains unchanged." Other subjective criteria will be considered presently. For any subjective criterion there may, however, be various statistical criteria, say, a 75 per cent threshold, so that there are, in fact, a series of possible horopters rather than *a* "horopter."

To turn to the sensory basis, the parallactic angles of the points on the Vieth-Müller circle are equal, and, the visual angles separating a particular point (such as *E*) from the fixation point *A* are equal for the two eyes. Owing, among other things, to optical differences consequent on differences in length and refractive power, the linear retinal separations are not always equal and the spatial values for equal retinal separations are not always equal. In consequence, the commonly stated requirement of identical physical relationships of corresponding points is not a correct generalization, although it may happen as an individual

2. Aguilonius, F.: Opticorum libri sex, Antverpiae, ex off. Plantiniana, 1613.

peculiarity. The following quotation from Best and Taylor[3] will illustrate the type of definition alluded to:

> For any fixation position of the eyes a line can be drawn by geometrical calculation along which any point is imaged on a corresponding point in each retina.

The retinocortical relations are also not simple. It is clear that factors other than retinal position influence fusion, to consider this aspect alone. Thus, of elements in the two figures of a stereogram having the same relative position on the two retinas, some will "break," while

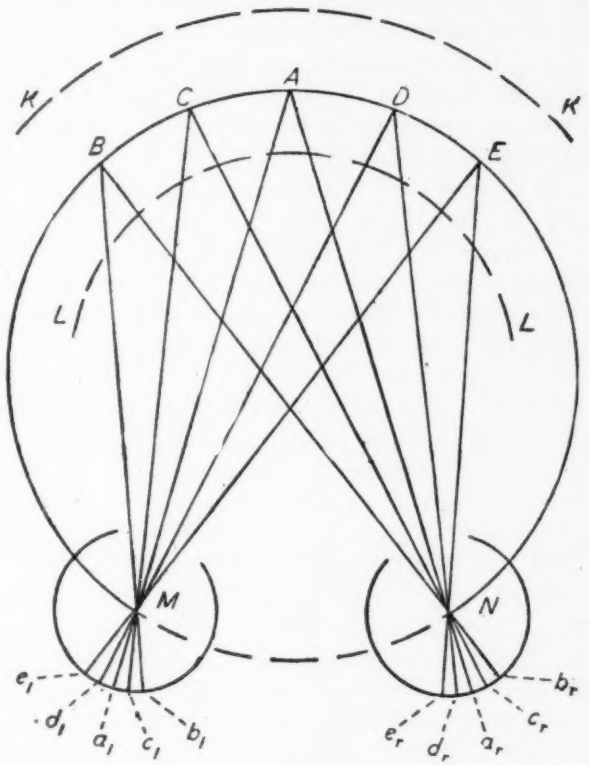

Fig. 2.—The horopter—a schematic drawing showing the Vieth-Müller circle and Panum's area.

others remain fused under the stress of induced divergence or convergence. Size, complexity of form, brightness and foveal or extrafoveal position appear to be some of the determining factors. From a consideration of these facts, it follows *(a)* that a purely anatomic definition of corresponding "points" cannot be satisfactory, and *(b)* that corres-

3. Best, C. H., and Taylor, N. B.: The Physiological Basis of Medical Practice, ed. 2, Baltimore, Williams & Wilkins Co., 1939, p. 1656.

ponding "areas" is a better term than "points,"[4] since fusion occurring without exact geometric correspondence is characteristic of the whole range of positions perceived as "single" and "near" or "far."

If one accepts the original, and most commonly accepted, criterion, that of singleness, the horopter is not a line but a band (Panum's area), shown in figure 2 between circles *K* and *L*. The horopter as a line would be a statistical construct representing the mean position of points in any section of the area. Criteria other than singleness have been proposed and other divisions of visual space experimentally determined. Ames, Ogle and Gliddon[5] cited Tschermak[6] as listing four criteria for determining the horopter. These are: (1) the criterion of "median single vision"; (2) the criterion of the "apparent frontal planes"; (3) the criterion of constancy of "visual direction," and (4) the criterion of the "maximal differential sensibility of depth." The quotation marks indicate Tschermak's terminology.

The first of these criteria is the conventional definition, leading to Panum's area aforementioned. The second criterion leads to the *Kernfläche*, or *Kernebene* of Hering,[7] the locus of points seen as equidistant with the fixation point. The third criterion was used by Ames, Ogle and Gliddon in determining the horopter by the grid nonius method. This is the locus of points seen by each eye as having similar directions.

Just as there are a number of statistical and subjective criteria, so there are numerous distances which may be arbitrarily termed thresholds; similarly, there are many surfaces which are of use in describing certain visual functions. Instead of the term "horopter," which is defined as the locus of points seen singly, it is suggested that one speak of surfaces and make use of two adjectives, one to describe the subjective and one to describe the statistical criterion for determining the threshold, *x*. Phrases such as "50 per cent single surface," or "75 per cent equidistant surface," or "90 per cent equidirectional surface" would be far less confusing than the single term "horopter." Such operational terminology, which includes a description of how the surface was determined, would carry with it the implication that there are a number of related surfaces.

4. Martin, E. G., and Weymouth, F. W.: Elements of Physiology, Philadelphia, Lea & Febiger, 1928, p. 687.

5. Ames, A., Jr.; Ogle, K. N., and Gliddon, G. H.: Corresponding Retinal Points, the Horopter, and Size and Shape of Ocular Images, J. Optic. Soc. America **22**:554, 1932.

6. Tschermak, A.: Optischer Raumsinn, in Bethe, A.; von Bergmann, G.; Embden, G., and Ellinger, A.: Handbuch der normalen und pathologischen Physiologie, Berlin, Julius Springer, 1930, vol. 12, p. 894.

7. Hering, E.: Der Raumsinn und die Bewegungen des Auges, in Hermann, L.: Handbuch der Physiologie, Leipzig, F. C. W. Vogel, 1879, vol. 3, pt. 4, pp. 343-601.

II. EXPERIMENTAL METHODS AND STATISTICAL ANALYSIS OF DATA

The preceding section dealt with the geometric and statistical aspects of the threshold, the angle of binocular parallax (η) and the horopter (the spatial locus of subjective equality). In the present section we shall discuss the experimental methods of assessing distance discrimination and the statistical technics of threshold determination.

As stated, binocular distance discrimination is dependent on slight differences between the two retinal images. Such differences can be produced *(a)* by two objects, the relative distances of which may be reported, or *(b)* by a stereoscope, which presents to the two eyes two slightly different pictures.

Since the threshold is affected by the conditions, a brief survey of the chief experimental methods follows.

The earliest measurement of binocular distance acuity by the rod technic is apparently that of von Helmholtz.[8] He placed three needles at a distance of 34 cm. and found that a change of 0.25 mm. in the position of the middle needle could be distinguished binocularly but not monocularly. Since von Helmholtz was interested only in demonstrating the superiority of binocular distance perception, he was content to record the threshold as "less than" 60.5 seconds. This point was stressed by von Kries.[9] The value of 60.5 seconds should, therefore, not be considered as a threshold, as has been done by some authors.

Brooksbank James[10] followed von Helmholtz but used only two rods. Howard[11] altered the James apparatus, and, with slight modifications, his test is still in use by the United States Army Air Corps. As used by Howard, the apparatus consisted of two rods separated by 6 cm., the central portions of which were seen through an aperture by the subject from a distance of 6 meters. The rods were exposed momentarily by a shutter, and the subject was required to tell whether the right rod was nearer or farther than the stationary left rod. Twenty judgments each were made for distance separations of the rods, increased by 5 mm. steps, and the linear threshold was taken as the difference in distance for which 75 per cent or more of correct answers were obtained.

The final modification of the test was to make the movable rod controllable by the subject, who attempted to place it at the same distance as the standard rod. The average deviation for from one to ten settings is used as the threshold.

There are many tests based on the principle of two or more objects whose relative distances are judged. A few will be mentioned. Disks instead of rods were used as targets by Howard[12] and Updegraff.[13] A set of white-headed

8. von Helmholtz, H.: Helmholtz's Treatise on Physiological Optics, translated by J. P. C. Southall, ed. 3, Ithaca, N.Y., Optical Society of America, 1925.

9. von Kries, J.: Notes, in von Helmholtz,[8] vol. 3, p. 375.

10. James, G. I. B.: On the Measurement of the Stereoscopic Visual Acuity, Lancet **1**:1763-1766, 1908.

11. Howard, H. J.: A Test for the Judgment of Distance, Am. J. Ophth. **2**:656-675, 1919

12. Howard, H. J.: Judgment of Distance with Semaphores and a Screen at 100 Meters, Arch. Ophth. **48**:461-474, 1919.

13. Updegraff, R.: The Visual Perception of Distance in Young Children and Adults, Studies in Child Welfare, Iowa City, University of Iowa Press, vol. 4, no. 4, 1930.

pins mounted on a black surface was used by Davidson.[14] The subject was asked to determine which pin protruded farthest. Short exposure time was a feature of Hering's *Fallapparat,* in which the subject viewed through a rectangular tube a fine thread and a ball which fell either behind or in front of the thread. In some modifications of this test a bead is suspended on the thread as a fixation and comparison object. Litinskiĭ [15] has recently used a similar method.

The second method, the stereoscopic, may be used in two forms. In one, the pictures presented to the two eyes differ in the separation of the various objects, such as letters. The subject judges the relative apparent positions of the objects, and his acuity is determined by the smallest difference which he can judge correctly. In contrast, a single variable stereogram may be used. In its simplest form the stereogram consists of two lines presented to each eye, in one pair of which the separation may be varied by the observer or the experimenter. When the separation of the two pairs is the same, most persons will see the fused images as two equidistant lines; if the separation of the variable pair is changed, the two lines will appear at different distances. In Howard's stereomicrometer [16] the subject controls the lateral position of one pair with a micrometer screw, and his task consists in setting the lines so that they appear equidistant. The well designed Pulfrich stereoscope [17] may also be used in this manner

It has already been stated that unless the experimental conditions, the subjective criteria and the statistical standards are specified, and the effect of these conditions on the results are known, comparison of the thresholds obtained by different workers is meaningless. The following values must be regarded in this light, merely as recorded thresholds of distance discrimination, and cannot be further analyzed here. Von Helmholtz, as already noted, obtained a threshold of "less than" 60.5 seconds; Stratton,[18] one of 24 seconds; Bourdon,[19] one of 5 seconds; Crawley,[20] one of 2.3 to 20 seconds; Howard,[11] one of 1.8 to 136.2 seconds; Andersen and Weymouth,[21] one of 2 seconds; Frübose and Jaensch,[22] one of 2 seconds, and Langlands,[23] one of 1.6 to 5 seconds. If an average value must

14. Davidson, M.: A Simple Device for Measuring Stereopsis, Am. J. Ophth. **18**:356-359, 1935.

15. Litinskii, G. A.: The Rapidity of Depth Perception, Vestnik oftal. **13**: 850-860, 1938.

16. Howard, H. J.: A Stereomicrometer, Am. J. Ophth. **3**:417-421, 1920.

17. Pulfrich, C.: Ueber eine Prüfungstafel für stereoskopisches Sehen, Ztschr. f. Instrk. **21**:249-260, 1901. Zeiss, C.: Neue Prüfungstafel für stereoskopisches Sehen, 1908.

18. Stratton, G. M.: A Mirror Pseudoscope and the Limit of Visible Depth, Psychol. Rev. **5**:632-638, 1898.

19. Bourdon, B.: La perception visuelle de l'espace, Paris, Schleicher frères & Cie, 1902.

20. Crawley, C. W. S.: Stereoscopic Vision, Brit. J. Photog. **52**:446-447, 1905.

21. Andersen, E. E., and Weymouth, F. W.: Visual Perception and the Retinal Mosaic: I. Retinal Mean Local Sign—Explanation of the Fineness of Binocular Perception of Distance, Am. J. Physiol. **64**:561-594, 1923.

22. Frübose, A., and Jaensch, P. A.: Der Einfluss verschiedener Faktoren auf die Tiefensehschärfe, Ztschr. f. Biol. **78**:119-132, 1923.

23. Langlands, N. M. S.: Reports of the Committee upon the Physiology of Vision: IV. Experiments on Binocular Vision, Medical Research Council, Special Report Series, no. 133, London, His Majesty's Stationery Office, 1929.

be given, that of 2 seconds suggested by Duke-Elder[24] seems not far wrong. The minimum requirement for service in the Army Air Corps is approximately 10 seconds, but as actually applied it varies widely.

The final step in distance discrimination is the statistical analysis of the data. This varies with the experimental method of determining the threshold. The three fundamental psychophysical methods, dating from Fechner,[25] have been listed by Boring[26] as follows: (*a*) the method of limits (minimal changes); (*b*) the method of right and wrong cases (constant method); (*c*) the method of average error (production method). The last two methods have been commonly used in determination of distance discrimination.

The method of average error as applied to the rod technic may be described briefly. A fixed standard and a movable comparison rod controlled by the subject are provided. The task is to place the comparison rod, initially set obviously far or near, at the same distance as the standard. The recorded settings of the comparison rod furnish a series of estimates of the position judged equidistant and may be arranged as a frequency distribution. Such a distribution may be described by a mean, or average estimate and a standard deviation, or variability of the estimates, about this mean. The mean is the position of subjective equality, E_s; the standard deviation indicates the accuracy with which the particular subject groups the settings about the E_s, and since some function of this scatter has generally been taken as the threshold, the simplest solution is to take the standard deviation itself as the threshold.

In the constant method a standard rod is also used, but the movable rod is successively placed at various points within the range corresponding to that obtained with the method of average error, and reports are required of the subject regarding its position relative to the standard. Several technical points in this method affect the results obtained, and hence require consideration. The most important are the time of exposure, the position and number of the stations and the categories of answers required.

The time of exposure controls fixation; if short, fixation may be restricted to a particular point, a matter of importance in determining the horopter. The stations, or fixed values of the stimulus, should lie within the range that would include all the settings of the average error method. The extremes should be far enough apart to provide clear contrast, but not nearer than 5 per cent to either end. A conventional number of stations is five, but smaller numbers (four, or even two) have been successfully used and possess certain advantages if normality of distribution need not be checked.

The use of a category of "equal" or "doubtful" answers has been condemned by several workers because of the marked effect on the threshold of the variability in attitude toward these answers. The two category report ("near" and "far") seems preferable and has been used by us.[27]

If the percentage of "near," or "far," answers obtained with the two category report are plotted on the *y* axis against the stimulus value of the stations on the *x* axis, a cumulative, or integral, curve is obtained which crosses its mirror image obtained from the contrasting answer at 50 per cent. From either curve, since they contain the same information, can be obtained the median (or mean, if the

24. Duke-Elder, p. 1078.

25. Fechner, G. T.: Elemente der Psychophysik, Leipzig, Breitkoff & Härtel, 1860.

26. Boring, E. G.: Sensation and Perception in the History of Experimental Psychology, New York, D. Appleton-Century Company, Inc., 1942, pp. 37-41.

27. Weymouth, F. W., and Hirsch, M. J.: Unpublished report.

curve is not skew) and the standard deviation. This is most easily accomplished by some sort of transformation of the percentage scale which will make the regression of percentage on the value of the stimulus linear if the basic distribution is normal. The frequency ratio, or probit method, developed by Bliss[28] for biologic assay, is well adapted to this purpose. Tables for transforming percentages to probits are available (Fisher and Yates[29]); the weighting of observations and the standard errors of the parameter estimates are, unlike those of the phi-gamma method, not matters of dispute. The method is time consuming but not more so than the classic phi-gamma method.

Having discussed the two most commonly used and appropriate methods for determining the threshold of distance discrimination, it may be well to consider the retinal counterparts of these procedures. These relations are suggested in figures 3 and 4. Figure 3 represents the situation when the method is that of average error. The seven stations of the movable rod are B_1 through B_7; the relative frequencies of the settings at these points are represented by the heights of the lines erected above B'_1 through B'_7. The tops of these ordinates are connected, suggesting the shape of the distribution if a large number of observations had been made. This approximately normal distribution has a mean at B'_4 and a standard deviation represented by the distance B'_4—B'_5 or any other of the equal spaces diagramed. The total range of six standard deviations might, at a distance of 6 meters, amount to 175 mm.

It will be seen from figure 3 that if the subject is fixating rod A and adjusting B for equidistance, four points on the two retinas must be considered, the images of A and B on each retina. Since A is fixated, its image on the left retina, a_l, and its image on the right retina, a_r, will fall on the two foveas, the primary corresponding points. The image of B on the left retina is always b_l. The entire distribution of point B is projected greatly minified on the retina about b_4. It must again be emphasized that the scale of the diagram is greatly distorted; for the conditions suggested, the separation of a_r and b_4 would be about 0.2 mm., and the range of the retinal distribution, b_1b_7, 0.0005 mm. This distribution, marking the actual points on the retina the stimulation of which gave rise to perceptions of a rod equidistant with A, is, like its external counterpart, normal and may be described by a mean, b_4, and a standard deviation, b_4b_5.

It is usually stated that point b_4 corresponds to point b_1; but it is immediately apparent that b_4 is a statistical concept and not a "point." A more important view is that 68 per cent of observations judged to be equidistant would fall between b_3 and b_5. The point b_4 may not have

28. Bliss, C. I.: The Calculation of the Dosage Mortality Curve, Ann. Applied Biol. **22**:134-167, 1935; The Comparison of the Dosage Mortality Data, ibid. **22**:307-333, 1935.

29. Fisher, R. A., and Yates, F.: Statistical Tables, Edinburgh, Oliver & Boyd, 1938.

the position suggested by the geometric construction, and B'_4 may not lie at the same distance as A, or instrumental equality, E_1.

Thus, for many observers, E_n proves to be nearer or farther than E_1. In addition to the random differences which might be expected, especially with small samples, many observers show a systematic and significant difference between E_n and E_1. The causes underlying this are complex. The actual retinal images and their separations are, of course, positioned in accordance with the rules of geometric optics. The

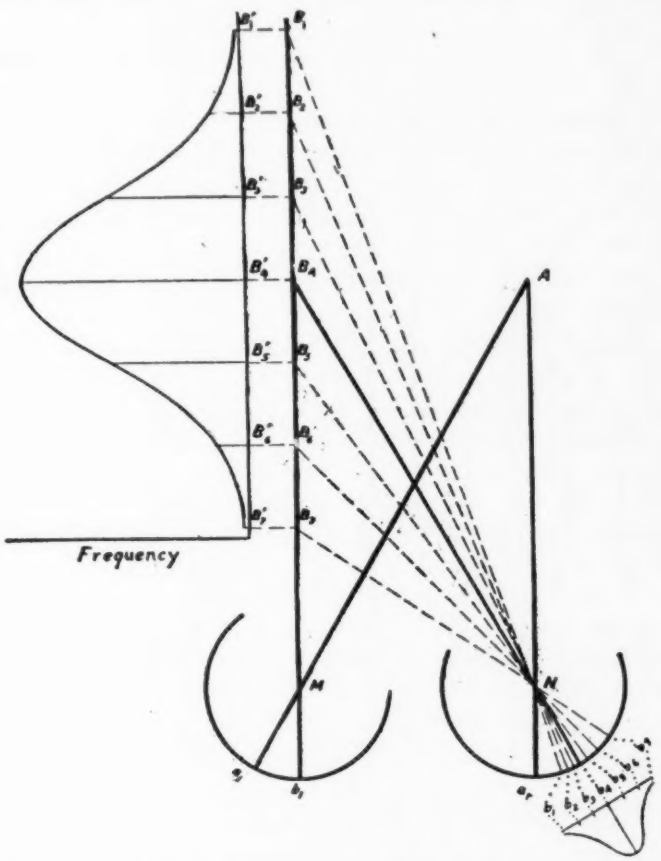

Fig. 3.—Relation of statistical measures of threshold of distance discrimination to retinal pattern determined by the statistical method of average error.

relative size of these images in the two eyes is affected by differences in the axial lengths of the eyes if emmetropic, or differences in length combined with the action of lenses in corrected ametropia. In addition, there is generally a difference in the space value of equal distances on the nasal and the temporal portions of the retina, and perhaps an over-all difference in "grain" between eyes. As a result, there often occurs a

difference in apparent image size, or aniseikonia, and this displaces the E_s by producing a retinal disparity in the case of external objects which are separated by equal visual angles.

Figure 4 illustrates the relations with the constant method. The conditions are similar to those of figure 3 except that the answers are "near" or "far" for each exposure of the rods. The curves which should be compared with the previous diagram represent the percentages of "near" and "far" answers at each of the stimulus stations, here located at separations of one standard deviation.

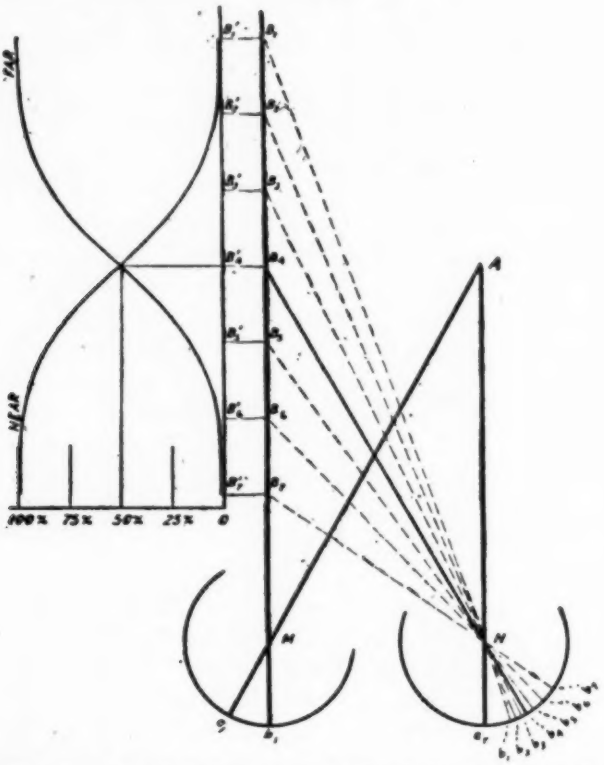

Fig. 4.—Relation of statistical measures of threshold of distance discrimination to retinal pattern determined by the constant method.

These curves represent the cumulative, or integral, form of the normal curve. Thus, when the rod is at B_7, there will be 0.1 per cent of "far" answers and 99.9 per cent of "near" answers. On passing to B_6, one standard deviation further away, there will be an increase to 2 per cent of "far" answers and a decrease to 98 per cent of "near" answers. When the rod is at B_4 the "far" answers will have increased to 50 per cent and the "near" answers will have decreased to 50 per cent. Thus, by summing from opposite ends, the "fars" from the near end and the "nears" from the far end, one obtains the cumulative normal

curves shown in the figure. As in the preceding example, the percentage distribution curve of the positions of the stimulus rod can be transferred in greatly reduced size to the retina and expressed in retinal distances.

It is possible now to define certain terms. In figure 3 the curve was so drawn that the mean, the position of subjective equality, E_s, coincides with the position of instrumental equality, E_1. This, as previously stated, does not always occur. These points may be transferred to the retinas; the two images of A fall on the foveas; $B_4 = E_1$ will be imaged at b_1 on the left retina, and at b_4 on the right retina. This may be called the theoretic corresponding point of b_1. The image of E_s will be the functional corresponding point of b_1; these two points will coincide in the rare cases in which E_s and E_1 coincide, or they may differ appreciably. There is obviously an area about the functional corresponding point which represents lesser correspondence, and the best measure of the size of this area is the standard deviation, S_x of the normal curve.

We have defined aniseikonia as an apparent difference in image size; if the image size is considered as the length of the line connecting the images of A and B on either retina, it will be seen that when E_1 and E_s fail to coincide by more than random error it is proof of aniseikonia.

It has been shown that threshold data contain information on two sensory characteristics, the position of subjective equality, E_s, a systematic "error" of the observer associated with aniseikonia, and a dispersion, or true, threshold, indicating the consistency of judgment. Obviously, any method of calculation which does not yield these two values sacrifices part of the information. The most commonly used threshold is the "average error" of the settings of the Howard apparatus. This is the mean deviation about the position of instrumental equality, which is larger because of the inclusion of E_s, but cannot be further analyzed. A more satisfactory measure is the root mean square error, R_{mse}, a statistical measure of which the standard deviation is a special case. The S_x is a measure of dispersion around the E_s or mean of the distribution; the R_{mse}, a measure of dispersion around the E_1. The relations are indicated in the following formula:

$$R_{mse} = \sqrt{E_s^2 + S_x^2}$$

While a single statistical measure presents possible advantages for a rough screening test, it should be clear that by its use much information is lost. The E_s is a measure of retinal functional correspondence, while the S_x, or threshold, is a measure of dispersion and, hence, of the variability of the individual subject. From the practical point of view, a high E_s may be corrected by the use of "size lenses," whereas the subject's characteristic variability of judgment cannot be altered. It would seem that if binocular acuity is worth measuring, it would be desirable to obtain all possible information.

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DISTANCE DISCRIMINATION

II. Effect on Threshold of Lateral Separation of the Test Objects

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IN THE current tests for distance discrimination based on the technic of Howard,[1] the movable and the comparison rods are separated laterally by 6 cm. Howard did not give his reasons for selecting this value; it may have been with the intention of simplifying the geometric relations on which the calculation of the angle of binocular parallax is based. The average interocular distance is approximately 6 cm., and in Howard's figures the lines joining the eye and the rod on the same side are parallel.

PRESENT INVESTIGATION

The present experiment was designed to determine the effect on the threshold of the lateral separation of the targets. The centers of the test objects were separated laterally by distances of 2, 4, 8, 16 and 32 cm.; since the subject was seated 17 meters from the test objects, the angular values of the separations were, respectively, 4′3″, 8′5″, 16′11″, 32′21″ and 64′42″. Assuming Gullstrand's value of 17.05 mm. as the distance of the nodal point from the retina, the retinal separations of the images were 20, 40, 80, 160 and 320 microns, respectively. Accurate fixation on one of the rods was maintained, and it may be assumed that its image fell on the foveas of the two eyes. The image of the other test object fell on pairs of corresponding areas, located at the distances just mentioned, lateral to the fovea.

Methods.—Accurate fixation of one of the test objects was desired, combined with an exposure time sufficiently short to preclude the possibility of any ocular movement. It was further desirable to have the apparatus similar to that of Howard, so that results obtained might be of use in the design of testing apparatus. Exposure of the targets for less than 0.1 second would safely eliminate the possibility of ocular movements, since Erdman and Dodge[2] found the reaction time

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The apparatus here described was constructed and the experiments were performed with funds made available by the Air Material Command, Wright Field, Dayton, Ohio.

1. Howard, H. J.: A Test for the Judgment of Distance, Am. J. Ophth. **2**: 656-675, 1919.

2. Erdman, B., and Dodge, R.: Psychologische Untersuchungen über das Lesen, Halle, Max Niemeyer, 1898.

of the ocular muscles to be between 0.162 and 0.170 second. The method was fundamentally that of Hering's falling ball apparatus, more recently used by Litinskii.[3]

The subject was seated 15 meters from a partition. An aperture 19 by 54 cm. in the partition permitted a view of a milk glass screen 3 meters further from the observer, illuminated to the same level as the partition and other walls in the field of view. A small red spot projected on the screen served as a fixation point. Between the partition and the screen, and above the field of view, were two tracks parallel to the long axis of the room and adjustable as to separation and height above the aperture. On these tracks ran two cars from which the test objects, metal rods 6 cm. long and 0.6 cm. in diameter, were released. A magnetic release controlled by a switch in the hand of the subject dropped the two rods simultaneously when the subject had fixated the red spot and was otherwise ready. The tracks and cars were so oriented that one rod was at a fixed distance (17 meters) and passed down directly in front of the red fixation point, which was automatically turned out at the moment that the rod was released. The other rod fell at a determined distance to the right or the left of the reference rod and at stations nearer or farther, as desired. The time relations were determined by the height of the tracks above the top of the aperture and in the present experiment were such that 0.104 second elapsed from the moment that the bottom of the rods appeared below the top of the aperture until the top of the rods disappeared behind the bottom of the opening. The entire rod was present in some part of the field for 0.05 second; it took the rod 0.03 second to pass a given point in the field at the top, and 0.02 second at the bottom, of the aperture.

The constant method was used with two categories of answers: the parameters were calculated by the probit method of Bliss and Fisher,[4] and the standard deviation was used as the threshold. The constant method is well known; a discussion of the reasons for its selection, details of its application and references are given in the first paper of the present series on distance discrimination.[5] Here it will suffice to point out the following aspects:

Forcing the answers into two categories, "near" and "far," eliminates the differences in subjects or in the reports of the same subject at different times with respect to the "equal" or "uncertain" judgments, and thus tends to stabilize thresholds. The probit method is superior to the phi-gamma method in the statistical rationale of its weighting and of its standard errors. The adoption of the standard deviation as the threshold (it will be called "threshold" in the remainder of the paper) utilizes the most stable measure of the distribution. This method is valid only for normal distributions, but, unlike the phi-gamma technic, presents a test by which abnormal distributions may be rejected. It is equivalent to using the distance from the 50 per cent point to either the 16 or the 84 per cent point, or their average, as the threshold. The threshold is more stable than that based on the 25 or the 75 per cent point.

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3. Litinskii, G. A.: The Rapidity of Depth Perception, Vestnik oftal. **6**: 850, 1938.

4. Bliss, C. I.: The Calculation of the Dosage Mortality Curve, Ann. Applied Biol. **22**:134-167, 1935. Fisher, R. A., and Yates, F.: Statistical Tables, Edinburgh, Oliver & Boyd, Inc., 1938.

5. Hirsch, M. J., and Weymouth, F. W.: Distance Discrimination: I. Theoretic Considerations, Arch. Ophth., this issue, p. 210.

Since the choice of stations affects the standard error of the threshold, care was taken to select 4 stations such that both the extreme near and far positions yielded between 80 and 90 per cent of correct answers. This selection was guided by an exploratory series of 10 trials at each of a number of stations. After the 4 stations were selected, 30 observations were made at each station, so that each threshold in this series is based on 120 judgments.

Ten series of observations were made on each of 4 subjects. Each series took about one-half hour, and not more than 2 series were made on any one day. With fixation on the right or the left rod, each of the five lateral separations previously mentioned were used. A random order, which was different for each subject, was used so that effects of practice and fatigue might be minimized for the group data.

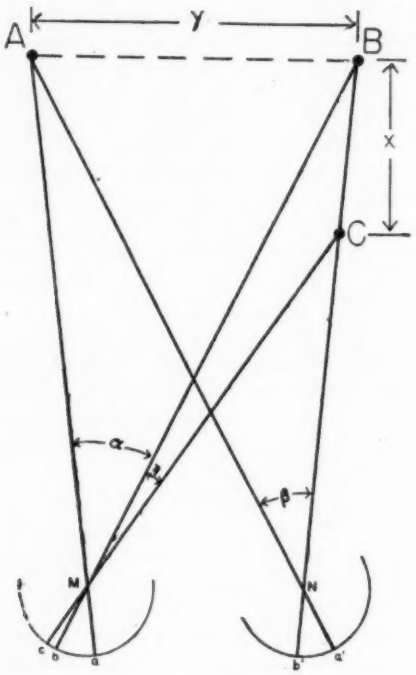

Fig. 1.—Schematic diagram of relations involved in binocular parallax.

The relations involved in binocular parallax are presented schematically in figure 1. To make these relations apparent, since the actual angles are minute, the scale of the diagram has been greatly distorted. The distance NC, for example, is actually fifty or one hundred times as great as BC, while MA is one thousand times as great as Ma.

The object A is assumed to be point fixated. When the movable rod is at B, at the same distance as A from the eye, the angles α and β are equal. If, now, the movable rod is advanced to point C, the distance x being the threshold, then angle η is the retinal disparity, or binocular parallax. The greater the distance y separating the test objects, the greater the angle α. The present experiment is concerned with the effect of the size of angle α on the threshold, η.

RESULTS

The 40 thresholds, each based on 120 judgments and expressed in millimeters, are presented in table 1, together with the averages for the 4 subjects and the angle of retinal disparity η based on these means. An analysis of variance on these thresholds was carried out to see what elements of the experiment had significant effects; the results are shown in table 2. There are three factors in the design of the experiment: the

TABLE 1.—*Thresholds (S_s) for Four Subjects Determined Under Ten Conditions*

Condition: Fixation	Condition: Angular Separation of Targets, Sec.	Threshold, Mm.: Subject 1	Subject 2	Subject 3	Subject 4	Average	Angle of Retinal Disparity (η) for Average, Sec.
Right	3,882	341.18	277.80	238.86	642.51	375.09	17.4
Right	1,941	241.28	248.16	194.90	218.73	225.77	10.5
Right	971	182.10	361.81	153.59	221.87	229.84	10.7
Right	485	246.10	284.71	133.31	385.51	262.41	12.2
Right	243	280.23	212.35	236.97	583.91	328.36	15.2
Left	243	374.43	540.07	232.80	537.62	421.23	19.5
Left	485	259.12	315.29	159.01	757.26	372.67	17.3
Left	971	300.88	179.96	168.48	240.46	222.44	10.3
Left	1,941	351.80	203.65	155.03	251.63	240.53	11.2
Left	3,882	383.42	297.09	296.56	339.38	329.26	15.3

TABLE 2.—*Sources of Variation in Thresholds of Distance Discrimination*

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Variance Ratio, F	5% Level	1% Level
Separation of rods (I)...	148,365	4	37,091	2.83	3.3	5.4
Fixation (F).....	10,846	1	10,846	....	...	...
Subjects (S).....	245,916	3	81,972	6.26	3.5	6.0
IF.....	35,463	4	8,866	....		
IS.....	152,792	12	12,733	....		
FS.....	6,645	3	2,215	.....		
IFS (error).....	157,251	12	13,104			
Total.....	757,278	39				
Separation (I).....	148,365	4	37,091	3.27	2.7	4.0
Fixation (F).....	10,846	1	10,846	....	...	...
Subjects (S).....	245,916	3	81,972	7.22	2.9	4.5
All interactions (error)...	352,151	31	11,360	....		
Total.....	757,278	39				

separation of the rods (I), fixation with the right or with the left eye (F) and subjects (S). Using the second order interaction of these three factors (IFS) as the error, only the difference between subjects is significant at the 1 per cent level. This is, of course, neither surprising nor important for our present purpose. Since none of the first order interactions is even as large as the mean square of the error, it is possible to combine all interactions into a single error term. On this basis, the separation is significant to about the 2 or 3 per cent level, but fixation is still without significance.

These findings justify two conclusions: 1. The separation of the rods has a significant effect on the thresholds, an effect which would probably have been clearer had more subjects been used. This point will be discussed in more detail shortly. 2. There is no significant difference between fixation on the right and that on the left. Accordingly, the eight values (4 subjects and two fixations) for each separation have been combined and are presented in table 3 as means, together with the binocular parallax, in seconds, and as a percentage of the angle of separation of the rods (100 η/α). Beside the average thresholds, the variability of the thresholds must also be considered. The standard deviation based on the eight values have been calculated for each of the five separations, and these are given in table 3 and are represented graphically as vertical bars above and below the average thresholds shown in figure 2. It is at once apparent that those separations which give the smallest thresholds also show the least variability. The thresholds obtained at separations of 971 and 1,941 seconds are less

TABLE 3.—*Average Thresholds for Five Retinal Separations*

Angular Separation of Targets (α), Sec.	Average Threshold, Mm.	Standard Deviation, Mm.	η, Sec.	100 η/α
243	374.80	156.77	17.39	7.16
485	317.54	195.17	14.73	3.04
971	226.14	72.58	10.49	1.08
1,941	233.15	57.76	10.82	0.56
3,882	352.18	125.35	16.34	0.42

variable than those at other points to the 5 per cent level, and in some comparisons to the 1 per cent level, of significance.

These results agree with the reports of the observers who said that judgments were difficult at both the least and the greatest separations. All thresholds tend, in the present experiment, to be large, since the time that any particular point of the retina was exposed to the image of the falling rod was only 0.02 to 0.03 second. A number of workers, including Cobb and Moss [6] and Graham and Cook,[7] have shown that acuity falls with shortened exposure, and it is probable that distance discrimination parallels visual acuity in this respect. Possibly the movement also reduced acuity.[8] Difficulty at the greatest separation might result from the reduced acuity at the extrafoveal point occupied

6. Cobb, P. W., and Moss, F. K.: Four Fundamental Factors in Vision, Tr. Illum. Engin. Soc. **23**:496-506, 1928.

7. Graham, C. H., and Cook, C.: Visual Acuity as a Function of Intensity and Exposure-Time, Am. J. Psychol. **49**:654-661, 1937.

8. Ludvigh, E.: Visibility of the Deer Fly in Flight, Science **105**:176-177 (Feb. 14) 1947.

by the unfixated image, or from the comparison of widely separated images. Weymouth and others [9] found that at 1 degree from the fovea visual acuity was reduced to 60 per cent. Difficulty at the least separation is less expected, since comparison might be thought to be easier. A closer scrutiny of the relation of the images, however, shows that their centers are separated by only 4 minutes and their inner margins by about 3 minutes. Since the rods are in motion and their images are of short duration, this small separation may scarcely have exceeded the effective resolving power of the eye and have justified the feeling "that the rods got in each other's way."

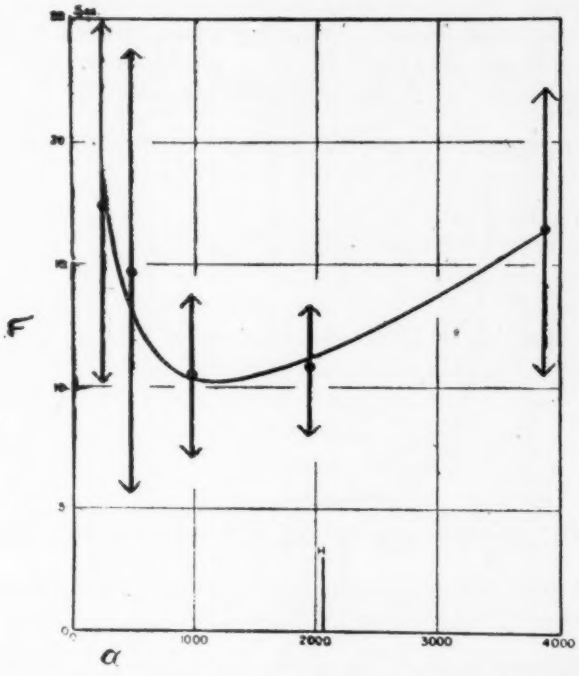

Fig. 2.—Effect of angular separation (α), expressed in seconds, on threshold (η).

It is probable that the minimum point (fig. 2) for the threshold is a compromise between the increasing threshold as the image departs from the fovea and the difficulty of resolving the images of the two rods at the smallest separations.

There are few data available in the literature for comparison in experiments in which the separation of the rods was varied. Andersen

9. Weymouth, F. W.; Hines, D. C.; Acres, L. H.; Raaf, J. E., and Wheeler, M. C.: Visual Acuity Within the Area Centralis and Its Relation to Eye Movements and Fixation, Am. J. Ophth. **11**:947-960, 1928.

and Weymouth,[10] working at 2 meters, used two separations giving angular values of 4,125 and 1,547 seconds, corresponding roughly to the two largest separations used in the present work. Although, owing to a difference of conditions, the thresholds cannot be compared directly, the limen at the greater separation was about 1.7 times that at the lesser; in the present work, the ratio of the two largest separations was only a little greater, i. e., 2.2. As far as these data go, they are in accord with the present findings.

Langlands,[11] also under conditions not permitting comparison with the present thresholds, studied the effect of separations of 0.5, 1, 2, 3 and 4 degrees. Over this range the threshold increased almost linearly with increase of separation. This observation agrees with our findings at comparable distances and indicates a continued increase of threshold to about four times the largest separation here studied.

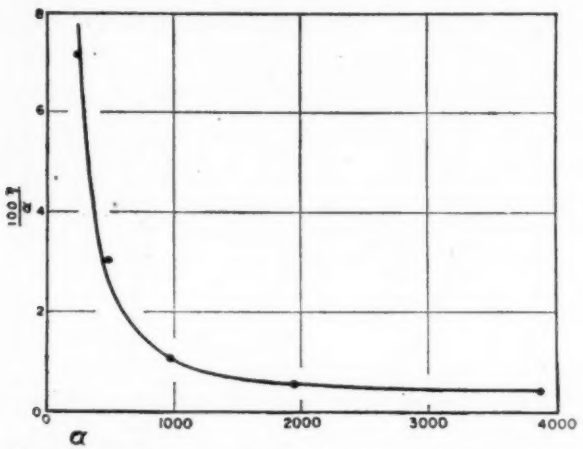

Fig. 3.—Effect of angular separation (α), expressed in seconds, on threshold, expressed as a per cent of the separation ($100\eta/\alpha$).

The minimum point of the curve of threshold on separation (fig. 2) clearly lies between 971 and 1,941 seconds, but the type of relation did not prove easy to fit, and the smooth line of the figure was derived indirectly, in a manner later to be described.

In addition to the direct relation of the threshold to the separation, the relative threshold may also be considered. In figure 3, $100\ \eta/\alpha$, or η as a per cent of α, has been plotted on α, the angle of separation. On

10. Andersen, E. E., and Weymouth, F. W.: Visual Perception and the Retinal Mosaic: I. Retinal Mean Local Sign—An Explanation of the Fineness of Binocular Perception of Distance, Am. J. Physiol. **64**:561-594, 1923.

11. Langlands, N. M. S.: Reports of the Committee upon the Physiology of Vision: IV. Experiments on Binocular Vision, Medical Research Council, Special Report Series, no. 133, London, His Majesty's Stationery Office, 1929.

this relative basis, the threshold falls continuously without a minimum, in a manner suggesting a hyperbolic relation. The asymptote toward which the relative threshold is tending proves to have a value of about 0.35, and by shifting the origin by this amount the curve is well fitted by a hyperbola having the formula:

$$\frac{100\eta}{a} = \frac{79{,}440}{a^{1.688}} + 0.35.$$

From this, the curve in figure 3 has been drawn.

Working from this basis, the formula

$$\eta = \frac{794.4}{a^{0.688}} + 0.0035a$$

is obtained, and from this the curve in figure 2 was calculated.

The orderly behavior of the relative threshold, falling from 7.16 to 0.42 per cent of the separation of the rods is a fact of obvious importance in the interpretation of experimental results, although this element has been generally disregarded.

On the basis of these data, the optimum separation of the rods would be approximately 19 minutes (1,140 seconds). At a distance of 6 meters, as the Howard apparatus is commonly used, this value would correspond to 33 mm., or about one-half the usual separation of 60 mm. Under the most favorable conditions the threshold might be expected to be reduced by about 12 per cent if a separation of the rods of 33 mm. was used, instead of the customary 60 mm.

SUMMARY

The effect of the separation of the rods on the threshold of distance discrimination was studied for five separations, ranging from 4 to 64 minutes.

The apparatus used employs the principle of Hering's *Fallapparat* and was designed to permit accurate fixation and to prevent ocular movements during observations. Because of the short exposure, the thresholds are rather large, and binocular parallax threshold did not fall below 10 seconds.

Over the range studied, the effect of separation is significant and systematic. The threshold is at a minimum at a separation of about 19 minutes and rises sharply at lesser, and more slowly at greater, separations.

In the design of apparatus and in the interpretation of experimental results, the dependence of the threshold on separation of the targets as well as other features of the stimulus pattern must be considered.

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SODIUM SULFACETIMIDE IN OPHTHALMOLOGY

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INFECTION of the conjunctiva and the ocular adnexa has long been a source of distraction to the ophthalmologist, the bacteriologist and, primarily, the patient. In the era before bacteria were discovered the ophthalmic textbooks contained no specific admonitions as to treatment, with the exception of the statement that when frank pus was noted heat in various forms relieved the irritation and at times caused pointing, opening and drainage of the abscess.

With the advent of modern knowledge of sepsis, smears and cultures of material from the conjunctival sac, the meibomian glands and the ciliary follicles were made. An enormous amount of laboratory work was accomplished and much appeared in the literature. It was found early that smears of material taken with a cotton applicator were not efficient, as many of the organisms were invaders of the tissue cells and few appeared on the surface. A method of scraping the conjunctiva with a platinum spatula yielded more evidence of the offending organism.

Two factors of importance must not be overlooked. First, many infections were self limiting; that is, because of natural defense mechanisms the infection cured itself without outside intervention. Second, human nature being what it is, the patient rarely consulted the ophthalmologist early in the course of the disease, so that by the time smears and cultures were made the amount of mixed infection (that is, infection caused by organisms other than the original one causing the disease) so obscured the picture that specific treatment was impossible.

In the next period antiseptics used for general infections were modified in such a way that injury to the delicate epithelial cells no longer prohibited their use in the conjunctival sac. It was found that silver preparations, while moderately efficacious, were often irritating and might cause argyrosis. The silver protein preparations had the defect last mentioned and, in addition, were excellent culture mediums. The use of certain specific drugs, such as ethyl hydrocupreine ("optochin"), zinc sulfate and copper sulfate, also had drawbacks. Ethyl

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hydrocupreine was painful to use, although it killed the pneumococcus. Zinc sulfate, while it had no bacterial effect in vitro, certainly was of benefit in chronic angular conjunctivitis due to Haemophilus duplex (Morax-Axenfeld bacillus), but other organisms were not affected. Copper helped trachoma, but mechanical expression was also necessary. In use of the aforementioned drugs and those to follow, the fact that only the surface cells were being treated must not be lost sight of.

Use of mercurial preparations has two important drawbacks: (1) Sensitivity to mercurial preparations is widespread, and (2) preparations concentrated enough to be bactericidal could not be obtained from the manufacturer or had not been accepted by the Council on Pharmacy and Chemistry of the American Medical Association. The aforementioned solutions were all aqueous, and antiseptics dissolved in phenol or alcohol are deleterious to the epithelium and other tissue cells.

Additional experimentation and therapy followed the discovery of the sulfonamide drugs. The 5 per cent ointment prepared for ophthalmic use was found not to be very efficacious; in addition, there were many reports of sensitivity. The sodium sulfanilamide could be dissolved only in 2 per cent solution, and little could be expected of such a weak solution.

Penicillin used locally, either in solution or in ointment form, is marvelous when penetration is at its maximum, and certainly when given intramuscularly, as in cases of gonorrheal conjunctivitis, it is generally most efficient in curing the disease.

The modern literature on bacteriologic investigations covering the past ten to twenty years is voluminous. However, much of the important work has been reviewed and confirmed by a few eminent authorities. It is my purpose, in order to save time and space, to bring to the attention, only the most important works. As far back as 1897, Morax [1] and Axenfeld [2] independently taught much concerning the diplobacillus which bears their conjoined names. Salle and his associates,[3] by substituting for the long-cherished phenol coefficient a method of growth of bacteria on living embryonic tissue contributed a logical criterion for the evaluation of an antiseptic. Thompson and his colleagues [4] showed the efficacy of various antiseptics in removing organisms from the conjunctiva due to properties of the antiseptic,

1. Morax, V.: Note sur un diplobacille pathogène pour la conjunctivite humaine, Ann. Inst. Pasteur **10**:337, 1896.

2. Axenfeld, T.: Ueber die chronische Diplobacillen-Conjunctivitis, Centralbl. f. Bakt. **1**:21, 1897.

3. Salle, A. J.; McOmie, W. A., and Shechmeister, I. L.: New Method for the Evaluation of Germicidal Substances, J. Bact. **34**:267, 1937.

4. Thompson, R.; Isaacs, M. L., and Khorazo, D.: A Laboratory Study of Some Antiseptics with Reference to Ocular Application, Am. J. Ophth. **20**:1087, 1937.

such as disinfectant rate, highest concentration which is nonirritating to the conjunctiva, influence of increased protein concentration on the disinfectant rate and toxicity of the antiseptic for leukocytes and for lysozym. Nye [5] reported that of many antiseptics in aqueous solution iodine solution had the best rating. Thygeson [6] in 1938 reviewed the literature on the treatment of conjunctivitis. His work has been outstanding. Subsequently, he [7] stated that sulfonamide compounds have revolutionized the treatment of trachoma, inclusion blennorrhea, lymphogranuloma venereum, gonorrheal conjunctivitis, streptococcic diphtheria of the conjunctiva (pseudomembranous conjunctivitis) and staphylococcic blepharoconjunctivitis. Later, with Braley,[8] he reported good results from local treatment with sulfonamide compounds of over 500 patients with acute or chronic catarrhal conjunctivitis. The history of modern therapy and chemotherapy was well outlined by Bellows,[9] whose work on absorption of the sulfonamide compounds in ocular tissues is well known to all. In Brazil, Sales [10] studied the bacteriology of conjunctival secretions. He analyzed the results of 5,369 examnations and found that the Koch-Weeks bacillus was the most prominent organism. He also discussed seasonal and meteorologic influences. P'an,[11] in a study of the absorption of sulfanilamide, had to use it over one hour in powder form to obtain a content of 44 mg. per hundred cubic centimeters in the aqueous.

In 1938 Dohrn and Diedrich [12] reported on the production of sulfacetimide (p-aminobenzene sulfonyl acetylimide) in the laboratory. Welebir and Barnes [13] found that the drug was as effective in acid as in alkaline urine and therefore placed no value on the p_H of the

5. Nye, R. N.: Relative in Vitro Activity of Certain Antiseptics in Aqueous Solution, J. A. M. A. **108**:280 (Jan. 23) 1937.

6. Thygeson, P.: Treatment of Conjunctivitis, Arch. Ophth. **19**:586 (April) 1938.

7. Thygeson, P.: Sulfonamide Compounds in Treatment of Ocular Infections, Arch. Ophth. **29**:1000 (June) 1943.

8. Thygeson, P., and Braley, A. E.: Local Therapy of Catarrhal Conjunctivit', with Sulfonamide Compounds, Arch. Ophth. **29**:760 (May) 1943.

9. Bellows, J., in Wiener, M.: Ophthalmology in the War Years, Chicago, The Year Book Publishers, Inc., 1946, vol. 1, pp. 176-181.

10. Sales, F. J. M.: Bacterioscopy of the Conjunctival Secretions, Arq. Inst. Penido Burnier **6**:390, 1942; Etiology and Pathogenesis: Bacterioscopy of Conjunctival Secretions, Rev. med. e cir. de São Paulo **1**:105, 1941.

11. P'an, S. Y.: Ocular Absorption of Sulfonamide Derivatives After Local Application, Proc. Soc. Exper. Biol. & Med. **49**:384, 1942.

12. Dohrn, M., and Diedrich, P.: Albucid, ein neues Sulfanilsaueredesivat, München. med. Wchnschr. **85**:2017, 1938.

13. Welebir, F., and Barnes, R. W.: The Use of Sulfacetimide in Bacillary Infections of the Urinary Tract, J. A. M. A. **117**:2132 (Dec. 20) 1941.

urine. Czekalowski [14] demonstrated that sulfacetimide acts as a stimulus to polymorphonuclear leukocytes. Rosenthal [15] found that sulfacetimide differs from the acetyl sulfanilamide formed in the body, as the acetylation occurs on the sulfonamide group and is therefore less toxic than sulfanilamide. Scott [16] advised use of a 10 per cent solution of sulfacetimide as a substitute for the Credé method of instilling a drop of 2 per cent silver nitrate in each eye of the newborn infant. Toland and Kornblueh [17] obtained excellent results in the prophylactic topical treatment of wounds. They observed no irritations or toxic symptoms due to the drug.

The local clinical use of a 30 per cent solution of sodium sulfacetimide was first reported by Dickson.[18] Under the auspices of the Ross Foundation for the Prevention of Blindness, in a trial period of six months, of 11,953 cases of ocular injuries, there were only 7 instances of corneal ulcer, while before the use of this drug 350 cases of corneal ulcer occurred in a three year period. Thus the preventive value is obvious. The rapid absorption of the drug into ocular tissue was attested by Robson and Tebrich.[19] They were satisfied that with the local use of 30 per cent sodium sulfacetimide the concentration in the conjunctiva, cornea, aqueous, sclera and even the iris was at its peak after fifteen minutes and that it was adequate after one hour. The work of Robson and Scott [20] provided evidence of the bactericidal action. Later Ginsburg and Robson [21] found that addition of a wetting agent increased the penetration of sulfacetimide into and through the cornea. They found that removal of the corneal epithelium increased the penetration, as the cornea acts as a barrier. Kuhn [22] observed no cases of

14. Czekalowski, J. W.: Studies on Stored Blood: VII. The Effect of Sodium Sulphapyridine, Albucid Soluble and Hydrogen Ion Concentration on Phagocytosis, Edinburgh M. J. **48**:405, 1941.

15. Rosenthal, S. M.: Pharmacology of the Sulfonamide Drugs, South. M. J. **35**:484, 1942.

16. Scott, G. I.: The Effectiveness of Sulphonamides When Applied to the Eye, Tr. Ophth. Soc. U. Kingdom **62**:3, 1942.

17. Toland, J. J., and Kornblueh, I.: Preliminary Report on Prophylactic Topical Use of Sodium Sulfacetimide, Indust. Med. **13**:946, 1944.

18. Dickson, R. M.: Traumatic Ulcer of the Cornea with Special References to Coal Miners, Brit. J. Ophth. **26**:529, 1942; First Aid Treatment of Industrial Eye Injuries, ibid. **27**:544, 1943.

19. Robson, J. M., and Tebrich, W.: Penetration and Distribution of Sodium Sulfacetimide in Ocular Tissues, Brit. M. J. **1**:687, 1942.

20. Robson, J. M., and Scott, G. I.: Local Effectiveness of Sodium Sulphacetimide (Albucid Soluble) in Treatment of Experimental Ulcers of the Cornea, Brit. M. J. **1**:5, 1942.

21. Ginsburg, M., and Robson, J. M.: The Effect of Detergent on the Penetration of Sodium Sulphacetimide (Albucid Soluble) into Ocular Tissues, Brit. J. Ophth. **29**:185, 1945.

22. Kuhn, H. S.: Sodium Sulfacetimide Thirty per Cent in Ophthalmology, Tr. Am. Acad. Ophth. **50**:210, 1946.

sensitivity. The drug compares favorably with penicillin as an anti-infective agent.[23] From Russia comes the report by Krasnov [24] that in 45 cases of serpiginous ulcer treated with sulfacetimide there were no perforations and that the remaining scars were very fine. The 10 per cent solution was ineffective. Sarkisov [25] had good results in treatment of gonorrheal ophthalmia in adults.

In May 1946 I was supplied with a quantity of a 30 per cent solution of sodium sulfacetimide.[26] It is said to be the only sulfonamide drug which can be prepared in such highly concentrated solution at the physiologic p_H of 7.4. I shall not give in detail the protocols of the clinical and laboratory experiments which have been accomplished during the past year. I shall, however, indicate the type of experiments which were carried out and the results. About 3,000 eyes with acute and chronic conjunctivitis were treated. There were no reactions which could be considered either as a sensitivity or as an allergic reaction. Three patients complained of burning, so severe it was necessary to stop the use of the drug. In many cases of bilateral infection controls were carried out as follows: (1) without medication; (2) with (*a*) 1 per cent silver nitrate and (*b*) 2 per cent silver nitrate neutralized with isotonic solution of sodium chloride; (3) with (*a*) 10 per cent and (*b*) 20 per cent mild silver protein U.S.P. ("argyrol"); (4) with hexylresorcinol, 1:2,500; (5) with nitromersol N.F. ("metaphen"), 1:5,000 and (*b*) 1:2,500 nitromersol; (6) with ethyl hydrocupreine ("optochin"), 0.5 per cent; (7) zinc sulfate, 0.5 per cent; (8) mercuric oxycyanide, 1:3,000, and, finally, (9) benzylkonium ("zephiran") chloride, 1:1,000. Smears and cultures were made in the early days of this work. However, as the usual effects were noted, and these seemed to have little influence on the result of treatment, it was decided that these procedures were unnecessary. In 365 eyes in which a foreign body was removed—from the lids, by simple wiping of the cornea or, when deeply embedded, by spudding out—a 30 per cent solution of sodium sulfacetimide was dropped in the eye for several days. No infection occurred in any case. The average mean periods of recovery for the various methods for all the cases of acute and chronic conjunctivitis were as follows: without medication, seven days; with 1 per cent silver nitrate, six days; with 2 per cent silver nitrate, five days; with 10 per cent mild silver protein, eight days; with 20 per cent mild silver protein, seven and a half days; with hexylresorcinol, 1:2,500, five

23. von Sallmann, L.: Simultaneous Local Application of Penicillin and Sulfacetimide, Arch. Ophth. **32**:190 (Sept.) 1944.

24. Krasnov, M.: Treatment of Serpiginous Corneal Ulcers with Albucid, Vestnik oftal. **23**:22, 1944.

25. Sarkisov, S. A.: Sulfacetimide in Gonorrheal Conjunctivitis of Adults, Sovet. med. **9**:24, 1945.

26. The solution was supplied by the Schering Corporation, Bloomfield, N. J.

days; with nitromersol, 1:5,000, five days; with nitromersol, 1:2,500, four and a half days; with ethyl hydrocupreine, 0.5 per cent, four and a half days; with zinc sulfate, 0.5 per cent, five days; with mercuric oxycyanide, 1:3,000, seven days; with benzylkonium chloride, 1:1,000 eight days, and with 30 per cent sodium sulfacetimide, three days.

Alexander Fleming's[27] comments concerning chemotherapy seem appropriate here:

> Local chemotherapy has been practiced since the days of Lister, but the underlying principles are even now little appreciated. These chemicals are said to possess this or that coefficient, and although this is perfectly true according to the tests employed, it generally has little bearing on their value as bactericidal agents in the human body. . . . As regards organisms such as the pyogenic cocci which are so intimately connected with ophthalmology, the chief defenses of the body are the phagocytic cells which pick up and destroy such bacteria after they have been opsonised by the blood or body fluids. It is easy to test the relative potency of a chemical to leucocytes and to bacteria by mixing the chemical in varying concentrations with suitably infected blood. The ferment lysozyme is seriously interfered with by a great many of the chemical antiseptics in common use. . . . In the past too much attention has been paid to the bactericidal action of chemical antiseptics, and better results might be hoped for if workers gave more care to the bacteriostatic action.

In my experience a 30 per cent solution of sodium sulfacetimide is an ideal antiseptic in cases of acute and chronic infections of the conjunctiva.

634 North Grand Boulevard.

ABSTRACT OF DISCUSSION

DR. PHILLIPS THYGESON, San Jose, Calif.: Topical application of the sulfonamide drugs to the external eye can now be evaluated on the basis of about eight years' experience. The enthusiasm of earlier years has been tempered, but there is no doubt of the value of the treatment in many types of bacterial infections of the lids, conjunctiva and cornea. Overshadowed in treatment of some infections by the greater effectiveness of penicillin, the sulfonamide drugs have a much greater range of action on bacteria and can, in addition, be used against certain nonbacterial infections, such as trachoma, inclusion blennorrhea, and lymphogranuloma venereum, for which penicillin is ineffective.

There has been considerable criticism, particularly from dermatologists, of the indiscriminate use of the sulfonamide drugs, especially with minor infections, because of the frequency of sensitization, which could prevent the use of the drug in the treatment of a serious infection, such as pneumonia or meningitis, when it would be life saving. It would seem desirable, therefore, to have a sulfonamide drug with low or negligible sensitizing properties. Sodium sulfacetimide, the drug advocated by Dr. Mayer, would seem to have much to offer in this respect.

27. Fleming, A., in Ridley, F., and Sorsby, A.: Modern Trends in Ophthalmology, New York, Paul B. Hoeber, Inc., 1940.

In my limited experience, sodium sulfacetimide in 30 per cent solution has been relatively nonirritating to the conjunctiva and cornea. Dr. Mayer has stated that no sensitization to the drug developed in his series of over 3,000 cases, in striking contrast to the frequency of sensitization to sulfathiazole, which, in my experience, has occurred in as high as 5 per cent of cases. The drug is not entirely free from sensitizing properties, however; Dr. A. E. Braley, of New York, reported a case of typical sensitization. Fortunately, there is a low incidence of cross sensitization among the sulfonamide drugs, and it is probable that sulfadiazine could be used with safety in a case of sensitivity to sulfacetimide. A cutaneous test with a sulfonamide-serum mixture before systemic use would seem to be indicated, however. Dr. Mayer reports an average mean period of recovery of three days in cases of acute and chronic conjunctivitis, as against a period of seven days in cases of the untreated disease. These figures are without much meaning unless further data are supplied as to the number of cases and the etiologic factors involved. I have no doubt that sodium sulfacetimide is effective in treatment of acute catarrhal conjunctivitis. I have grave doubts, however, of its value in many cases of chronic conjunctivitis when applied in solution, since in a high proportion of cases chronic conjunctivitis is secondary to blepharitis, which is not reached by the solution. The lid margins are never wetted properly with solutions, and only an ointment could be expected to maintain an effective concentration of the drug in a case of blepharitis. It must be remembered that the sulfonamide compounds, unlike penicillin, are not bactericidal, but are only bacteriostatic and require a definite time interval for action.

The value of sodium sulfacetimide in the prophylaxis of corneal infection after foreign bodies is of great interest. I can see no reason that this or similar sulfonamide substances should not eventually replace silver nitrate in the prophylaxis of ophthalmia neonatorum. In addition to preventing gonococcic infection, the sulfonamide drugs might also be expected to control inclusion blennorrhea.

What is now needed is a survey of ocular infections to determine the incidence of sulfonamide-resistant strains of bacteria. Such a study would be a great help in enabling ophthalmologists to employ topical sulfonamide therapy effectively.

Dr. Mayer has performed a real service in calling attention to the efficacy of this more recently developed sulfonamide drug and to its lack of sensitizing properties.

DR. EUGENE W. ANTHONY, Fulton, N. Y.: Dr. Mayer has given an excellent summary of the value of this drug, which is no doubt relatively new to most of us. It was introduced in Germany in 1938 but gained its great popularity in ophthalmology in Great Britain in 1941 and 1942. There, it is commonly called "albucid." I spent two and a half years as opthalmologist to one of the army hospitals in England during the war. When we arrived in late 1942, there were nine ophthalmologists in that theater, and the three most discussed words of that time were Duke-Elder, Colonel Vail and "albucid." During 1943, owing to the generosity of our hosts, we were invited to all the British ophthalmological meetings, both local and in London. We each spent two weeks at Moorfields Eye Hospital and visited many of the other ophthalmic hospitals of the country, including those at

Birmingham and Glasgow. We found a great deal of enthusiasm for the new drug "albucid." It was soon obtained for our army on lend-lease from the British by the work of Colonel Vail and Brigadier General Duke-Elder. Those of us in the stationary hospitals found it to be the best available drug for the conditions that Dr. Mayer has mentioned. It was used prophylactically in ocular wounds of all battle casualties and its instillation was to be routine in cases of gas casualties.

With the advent of penicillin in 1944, the use of "albucid" decreased in the larger army hospitals, but since it was not available to civilians, it was still the most popular ophthalmic drug in England when I left in 1945. I have been surprised to find so little mention of this drug in the ophthalmic literature of the United States, and this report has been very timely. I hope that Sir Stewart Duke-Elder will say something of the present status of this drug in England.

DR. OSCAR WILKINSON, Washington, D. C.: I wish to report therapeutic results in cases of ulcer of the cornea with the use of a concentrated solution of this drug. The secret of the results with this drug is the concentration of the solution. Recently, I had the opportunity of treating 3 patients with dendritic ulcer. They had received the ordinary remedies for three or four weeks. Penicillin or an ointment containing 5 per cent sodium sulfathiazole had been used with atropine and the ordinary remedies, and 2 of the patients had protein therapy. Within twenty-four hours, with the drug administered every two hours, each patient had striking relief, and within three and a half or four days the eyes were practically clear. I cannot account for such rapid relief except that the drug is a very efficient remedy in this type of ulcer. With some other ulcers it did not seem so effective. In fact, I think it is like the other sulfonamide drugs; if there is a closed source of infection, the drug will not work so well.

Recently I had a patient who had had recurrent ulcers for three or four weeks; he also had dental abscesses. He immediately improved with the sulfonamide treatment after extraction of his teeth.

DR. LEO L. MAYER, St. Louis: I agree with Dr. Thygeson that the future use of antiseptics is a large study, but my reason for presenting this paper was the fact that the drug had been in general use for so long in Europe and had had so little mention in the literature here, and it seems to be a most efficient drug.

I also agree with Dr. Thygeson that there is practically no drug in use to which some one is not sensitive; I was fortunate that I had no reactions in the patients I treated. I understand that Dr. Hedwig Kuhn, of Hammond, Ind., also made such a report.

Obituaries

ERVIN TÖRÖK, M.D.
1877-1947

Ervin Török died on Nov. 4, 1947, at the age of 70. He had practiced ophthalmology in New York for forty years. Dr. Török was a native of Hungary, where he graduated from the University of Budapest and received his doctor's degree in 1899. He received his preliminary education in ophthalmology in Budapest at the clinics of Grósz and Blaskovics. After several years of postgraduate train-

ERVIN TÖRÖK, M.D.
1877–1947

ing at the ophthalmic hospitals of the Universities of Budapest and Berlin, he arrived in the United States in 1905 with a letter of introduction to Dr. Herman Knapp and then became resident at the New York Ophthalmic and Aural Institute. He was made full surgeon in 1913, when the hospital moved uptown and its name was changed to

the Herman Knapp Memorial Eye Hospital. He resigned as surgeon in 1927, to become professor of ophthalmology at the New York Polyclinic Hospital.

In 1912 he was appointed ophthalmologist at the Beth Israel Hospital in New York city; he organized the department of ophthalmology at this rapidly growing hospital, and he remained its chief for twenty-five years, until his resignation in 1938. His other, many hospital affiliations included Beekman Street Hospital and several institutions in Westchester County. In his later years, Dr. Török remained in active service only at the New York Polyclinic Medical School and Hospital. His interests there were equally divided among postgraduate teaching, surgery and clinical ophthalmology.

He became a member of the American Ophthalmological Society in 1912.

Dr. Török published papers both in Hungarian and in English on various, mostly surgical, subjects, and he is the author, together with Dr. Gerald H. Grout, of "Surgery of the Eye, a Handbook for Students and Practitioners," which was published in English in 1913 and later translated into Spanish. The book describes the surgical technic of the Blaskovics clinic.

Ervin Török's knowledge and experience in clinical, and especially surgical, ophthalmology was vast. It was a pleasure to watch the facility of his surgical skill. He was one of the first in this country to perform the scleral resection (Müller's operation) for high myopia. He also devised a method of intracapsular extraction consisting in grasping the anterior capsule with a blunt forceps and then extracting the lens by traction and by exerting pressure according to the usual von Graefe procedure.

Like so many physicians of his generation, he was a great clinician of the old school. But those who knew him well will probably remember him best for his kindness toward all his friends, his students and even the humblest of his clinic patients. During a close and almost daily association for over a dozen years, I do not remember having seen him lose his patience even once. To his very end, tragically aware of the nature of his fatal disease, he did not seem to lose interest in his patients. His concern for their welfare was equaled by their devotion to him. In those who had the privilege of being close to him, he will live on and his memory will endure.

ERNST F. LYON, M.D.

News and Notes

EDITED BY DR. W. L. BENEDICT

GENERAL NEWS

Training for Orthoptic Technicians, George Washington University School of Medicine.—The training of orthoptic technicians will be resumed by the Department of Ophthalmology of the George Washington University School of Medicine, Washington, D. C., beginning April 1, 1948. The training consists of six months of didactic and practical instruction and two months of "internship." Preference will be given to students who plan to combine the teaching of other students with the administration of orthoptic procedures in their respective communities.

The course of instruction will be under the direction of Dr. Ernest Sheppard, professor of ophthalmology, George Washington University School of Medicine, and Mary Everist Kramer, supervisor of the Department of Orthoptics of the George Washington University Hospital. The staff of the Department of Ophthalmology will assist with the teaching. It is anticipated that the students will have the opportunity of visiting other orthoptic clinics in the nearby vicinity during their period of internship.

Information regarding the orthoptic courses can be obtained from Dr. Ernest Sheppard, 1801 K Street N. W., Washington 6, D. C.

The Sanford R. Gifford Memorial Lecture.—The fourth annual Sanford R. Gifford Memorial Lecture was given at the Murphy Memorial Auditorium, Chicago, on Monday, Jan. 26, 1948, by Dr. Lawrence T. Post, of St. Louis. The subject of the lecture was "Practical Considerations in the Diagnosis and Treatment of Strabismus."

American Board of Ophthalmology.—Practical examinations of the American Board of Ophthalmology for 1948 will be held at Baltimore, May 20 to 25, and at Chicago, October 6 to 9. For further information, apply to Dr. S. Judd Beach, Cape Cottage, Maine.

UNIVERSITY NEWS

Post-Graduate Course in Ophthalmology, University of Michigan Medical School.—The School of Post-Graduate Medicine of the University of Michigan Medical School announces the annual postgraduate course in ophthalmology for qualified physicians, May 6, 7 and 8, 1948, to be given at the Horace H. Rackham Graduate Building, Ann Arbor, Mich., under the direction of the department of ophthalmology, University of Michigan. Complete program and details will be mailed on request to Dr. Howard H. Cummings, chairman of the School of Post-Graduate Medicine, University Hospital, Ann Arbor, Mich.

Abstracts from Current Literature

EDITED BY DR. WILLIAM ZENTMAYER

Conjunctiva

CLINICAL SIGNS OF DIAGNOSTIC IMPORTANCE IN CONJUNCTIVITIS. P. THYGESON, J. A. M. A. 133: 437 (Feb. 15) 1947.

There are a number of clinical signs, both gross and biomicroscopic, which are of importance in the diagnosis of conjunctivitis. Changes in the regional lymph nodes, the lid margins, the limbus and the cornea are of almost equal diagnostic importance with those occurring in the conjunctiva itself. By clinical examination alone it is possible to identify many of the various etiologic types of conjunctivitis. When these clinical observations are correlated with cytologic and bacteriologic studies, the cause can be determined in a high percentage of cases.

J. A. M. A. (W. ZENTMAYER)

Cornea and Sclera

CORNEA VERTICILLATA. M. GRUBER, Ophthalmologica 112: 88 (Aug.) 1946.

In a previous article (*Ophthalmologica* 111: 120, 1946) the author had reported cases of this rare corneal disease. In the second article, he describes additional cases of cornea verticillata in a second family. He believes that it is an unusual hereditary variation of physiologic character, but the manner of transmission is not as yet completely known. Good illustrations of the condition are given in the paper.

F. H. ADLER.

BIOLOGIC INDICATOR OF SUCCESS IN TRANSPLANTATION OF THE CORNEA: REPORT OF 124 CASES. V. ROSHCHIN, Vestnik oftal. 24: 47, 1946.

Roshchin performed corneal transplantations in 159 cases from 1938 to 1941. Of this series, only 124 are analyzed here, namely, the cases in which operation was performed prior to 1940, as in these cases the time of observation was sufficient for evaluation of permanent results. An increase of transparent over semitransparent transplants was noted for each successive year as a result of improvement in the operative technic. The second factor of improvement in corneal transplantation was the character of the leukoma. Of 20 cases of leukoma simplex, transparent transplants were obtained in 12, or 60 per cent, because there was a sufficient amount of normal corneal elements in the host's cornea. Of 42 cases of adherent leukoma, transparent corneas were obtained in only 16, or 38 per cent. This poor result was probably due to adhesions between the leukoma and the iris, which might produce secondary glaucoma and a proliferating membrane behind the transplant, thus minimizing the results of the transplantation. Of 62 cases.

of total leukoma, transparent transplants were obtained in 11, or 17.9 per cent, the poor success being the result of dense scars, or of membranous cataract adherent to the leukoma and the absence of normal corneal elements. Patients with total leukoma have the most unfavorable prognosis, but, at the same time, they are the most deserving of operation, particularly if the leukoma is bilateral. The problem of restoring sight to patients of the last category is still to be solved.

O. SITCHEVSKA.

Experimental Pathology

TREATMENT OF LEWISITE AND OTHER ARSENICAL VESICANT LESIONS OF THE EYES OF RABBITS WITH BRITISH ANTI-LEWISITE (BAL) [2,3-DIMERCAPTOPROPANOL]. I. MANN, A. PIRIE and B. D. PULLINGER, Am. J. Ophth. **30:** 421 (April) 1947.

From experiments on rabbits, Mann, Pirie and Pullinger found that 2,3-dimercaptopropanol (BAL) caused little irritation to rabbit eyes, but that if instilled within five minutes after a destructive dose of lewisite (B-chlorovinyldichloroarsine) it neutralized the effects of the latter and if its instillation was delayed up to twenty-five minutes it saved the function of the eye, although partial permanent damage remained. It was not effective against mustard gas (2-chloroethylsulfide) when this was used with lewisite.

W. S. REESE.

General

THE COLD PRESSOR TEST IN OPHTHALMOLOGY. J. A. VAN LOON, Ophthalmologica **112:** 63 (Aug.) 1946.

The cold pressor test is a standard method of measuring the reaction of arterial blood pressure and was first described by Heinz and Brown (Heinz, E. A., and Brown, G. E.: *Proc. Staff Meet., Mayo Clin.* **7:** 332, 1932). The procedure consists in measuring the patient's blood pressure while in the prone position during an interval of thirty minutes until the final resting value is obtained. When this has been reached, the patient plunges his hand down to the wrist for one minute in a basin with ice water, and during the immersion the blood pressure is taken every thirty to sixty seconds. The patient then withdraws the hand from the ice water, and the blood pressure is again taken, until it has returned to the previous value.

In the normal subject, the immersion of the hand into ice water causes a rise of blood pressure which is about 12 mm. of mercury for systolic and 10 mm. of mercury for diastolic pressure. Patients whose reaction exceeds 12 and 10 mm. of mercury, respectively, are called hyperreactors. In some cases a hyperreaction amounts to a maximum of 22 mm. of mercury for the systolic pressure and 18 mm. of mercury for the diastolic pressure. These cases are generally found among patients with hyperthyroidism, neurocirculatory asthenia and Raynaud's disease. The present paper concerns the evaluation of the changes in blood pressure in 12 patients with spasm of the retinal arteries and 18 patients with thrombosis of the retinal veins. The author found that the patients with spasm of the retinal arteries acted as hyperreactors,

whereas the majority of patients with venous thrombosis showed no rise of blood pressure due to the cold. From this, the author concludes that the conception of venous thrombosis appearing in consequence of a temporary spasm of the supplying artery becomes highly improbable.

F. H. Adler.

General Pathology

A Contribution to the Knowledge of Ocular Siderosis and Posterior Degenerative Pannus. A. Loewenstein and J. Foster, Am. J. Ophth. 30: 275 (March) 1947.

Loewenstein and Foster give the findings in an eye which had retained an intraocular foreign body for twenty-two years. They found iron in Bowman's membrane; the zonular fibers, which had ruptured; the lens capsule; the retinal periphery; the choroid, and the peripheral hexagonal cells. There was a granular substance between the choroid and the retina, with a remarkable, probably vascular, network, a highly developed posterior degenerative pannus, the vascular walls of which were completely infiltrated with fat. W. S. Reese.

Glaucoma

New Trends in Study of Glaucoma. A. Samoilov, Vestnik oftal. 24: 3, 1946.

Samoilov reviews briefly the numerous theories of the pathogenesis of glaucoma. The three cardinal symptoms of prodromal glaucoma, namely, disturbance of visual function, increased intraocular tension and ophthalmoscopic changes, are, rather, manifestations of late stages of glaucoma. The only early symptom is the glaucomatous edema of the retina and the appearance as a result of the edema, of pericentral (or ring) scotomas (as demonstrated by Dashevsky). Many complaints, such as the seeing of colors of the rainbow and blurring of vision, are based on the edema of the eye. The scotoma due to the retinal edema decreases not only with calcium iontophoresis, but also with instillation of pilocarpine into the eye. On this basis Samoilov devised his campimetric pilocarpine test. Pilocarpine decreases the glaucomatous scotoma regardless of whether the intraocular tension is reduced or remains unchanged; the adaptation curve is also normalized with calcium iontophoresis. Analysis of a number of cases in which operation was performed for glaucoma shows that even though the intraocular tension remained normal in 80 to 90 per cent visual function was preserved only in from 20 to 40 per cent of the surgical cases.

The pathologic study of blindness due to glaucoma showed that the immediate cause of blindness was the destruction of the nerve elements of the retina and the optic nerve.

Thus, Samoilov concludes that the basic element in the glaucomatous process in the initial period is the retinal edema with characteristic scotomas, which decrease under the action of pilocarpine. In the later stage of glaucoma the visual fields begin to change on the nasal side and the scotomas do not disappear or decrease with instillation of pilo-

carpine. Gradually, the edema is replaced with atrophy of the retinal tissue.

This concept offers a broad path for study of the complexities of the eternal problem of glaucoma and its pathogenesis. O. SITCHEVSKA.

Injuries

OCULAR HISTOPATHOLOGY OF SOME NAGASAKI ATOMIC-BOMB CASUALTIES. T. F. SCHLAEGEL JR., Am. J. Ophth. **30**: 127 (Feb.) 1947.

Schlaegel reports his observations on sectioned eyes of patients who died of the effects of the Nagasaki atomic bomb irradiation one month after the bombing. The histologic changes may be classified as those apparently due to direct irradiation and those due to the systemic condition. The cornea and lens may have been damaged by direct irradiation. Some of the corneas were observed to be denuded, with evidence of epithelial regeneration. The lenses might be in the early stages of developing radiational cataracts, as evinced by small vacuoles in the superficial cortex and thickening of the posterior capsule. The following changes were due apparently to the patient's systemic condition: serous exudation into and from the ciliary body; invasion of the eye by bacilli; septic choroiditis; nodular cellular infiltration of the retina; fibrin nets on the surface of the retina; and, in 1 case, a striking distention of all the ocular vessels with white cells, most of which were mononuclear. W. ZENTMAYER.

Lids

SOME METHODS OF LID REPAIR AND RECONSTRUCTION. S. A. FOX, Am. J. Ophth. **30**: 190 (Feb.) 1947.

Fox found that by using a series of acrylic forms, socket reconstruction with epidermis, both total and subtotal, is expedited and facilitated. Use of the Padgett dermatome assures a uniformly thin graft, which is easily handled if the technic outlined is followed. The middle of the inner surface of the arm is favored as the donor site. W. S. REESE.

Methods of Examination

ELECTROENCEPHALOGRAPHY AND OPHTHALMOLOGY. A. CALLAHAN and F. C. REDLICH, Am. J. Ophth. **29**: 1522 (Dec.) 1946.

Callahan and Redlich give a brief résumé of the history of electroencephalography, some of its physiologic facts and its clinical use. The technic and its application to ophthalmology are discussed. The authors have employed it to record the galvanic response of the skin after visual stimulation and thus been able to differentiate true and false blindness. It has also aided in localizing cerebral lesions with visual defects. W. S. REESE.

REGARDING GONIOPHOTOGRAPHY. R. R. BARRIOS and R. V. BARRIÈRRE, Am. J. Ophth. **30**: 49 (Jan.) 1947.

Barrios and Barrièrre use Goldman's contact lens and the Haag-Streit slit lamp for goniophotography, placing a Leica camera in the

position of one of the oculars. This camera is provided with a microscopic device which permits the exact focusing of the part to be photographed. They believe that the perfection of this technic, especially with color films, will be most useful.

W. S. REESE.

Neurology

THE AUTONOMIC NERVOUS SYSTEM IN OCULAR DISEASES. D. O. HARRINGTON, Am. J. Ophth. **29:** 1405 (Nov.) 1946.

The relations between the eye and the autonomic nervous system are reviewed, with special reference to possible effects on ocular physiology.

The autonomic stimuli are enumerated and found to be intensely active under wartime conditions of living. Special emphasis is placed on the importance and frequency of psychic trauma as a cause of autonomic instability and of the production of both physiologic, or functional, and pathologic, or organic, ocular changes.

Clinical studies have been made on autonomically unstable persons, including certain studies on the peripheral vascular system. The results have been correlated with certain physiologic dysfunctions and pathologic changes in the retina.

The clinical picture of vasoneurotic diathesis of the autonomically unstable person is described, and it is noted that the only constant factor in all cases of central angiospastic retinopathy is the autonomic instability.

The ocular manifestations of dysfunction of the autonomic nervous system reported were as follows: (*a*) central angiospastic retinopathy, (*b*) ocular changes in Raynaud's disease, (*c*) amaurosis fugax, (*d*) migraine and (*e*) commotio retinae. Typical cases of each condition are presented.

It is emphasized that the difference in amaurosis fugax, central angiospastic retinopathy and Raynaud's disease are of degree only.

The condition known as migraine is a cerebral vasospastic disturbance with predominant ocular symptoms.

Commotio retinae, which embraces all conditions producing retinal edema from chemical vasomotor disturbances, is a local rather than a general autonomic response.

Psychic trauma in a susceptible person can produce as profound organic changes in connection with the autonomic nervous system as extremes of temperature, anoxemia or direct physical trauma. The greatly increased wartime incidence of certain disturbances of autonomic origin can be explained in no other way.

The almost constant association of pain with these ocular lesions can best be explained as causalgia or sympathalgia.

W. S. REESE.

HEREDITARY NYSTAGMUS OCCURRING AS A SEX-LINKED CHARACTER RECESSIVE IN THE FEMALE. C. W. RUCKER, Am. J. Ophth. **29:** 1534 (Dec.) 1946.

Rucker found 21 cases of nystagmus in a study of six generations in a family tree of 231 members. All were males, who inherited the defect

from unaffected females. In no case did a male transmit it to his son. The manner of inheritance seems not to be related to associated head movements.

W. S. REESE.

THE INFLUENCE OF BARBITURATE ON VARIOUS FORMS OF NYSTAGMUS. M. B. BENDER and F. H. O'BRIEN, Am. J. Ophth. 29: 1541 (Dec.) 1946.

From their studies of intravenous injection of sodium amytal, Bender and O'Brien conclude that barbiturates in mild doses interfere with ability to control ocular movements and ocular fixation by action on the cerebral cortex, the brain stem and intermediate neuronal structures. Ocular movements not involving a cortical component might be altered by barbiturate as a result of its action on the brain stem.

W. S. REESE.

MECHANISM OF MOTION SICKNESS. G. MORTON, A. CAPRIANI and D. MCEACHERN, Arch. Neurol. & Psychiat. 57: 58 (Jan.) 1947.

Motion sickness was produced in human subjects by means of a machine designed to reproduce the wayward movements of a ship at sea. The authors proved that the tendency to attribute motion sickness entirely to psychogenic causes is unwarranted and against the facts. They found that motion sickness can be produced in practically every one if the right type of motion and proper position of the head are used. They produced it in dogs. Bilateral labyrinthectomy abolished it in dogs which had previously been highly susceptible.

In addition to psychologic factors, the authors investigated many different mechanisms that have been blamed for motion sickness, such as visual and kinesthetic incoordination, movement of heavy viscera, changes in blood chemistry, vascular instability, carotid sinus reflexes and labyrinthine stimulation. They conclude that the most important factor in motion sickness in man is probably stimulation of the utricles by linear accelerations in the vertical plane of the head.

Evidence that incoordination of visual and kinesthetic sensations plays a minor role is the fact that no amount of visual orientation can prevent sickness in susceptible people if they are exposed to the proper type of motion. Attention is called to the experiment by Jasper and Fields, who took moving pictures from the subject's seat in a moving swing. These were shown for over thirty minutes to a group of students in a classroom. No sickness was produced.

S. R. IRVINE.

Operations

METHOD OF SUPPLYING ADEQUATE AIR TO PATIENTS DRAPED FOR EYE OPERATIONS. L. RICHMOND and B. FRIEDMAN, U. S. Nav. M. Bull. 46: 88 (Feb.) 1946.

Perforated rubber tubing, ½ inch (1.3 cm.) in diameter, is fastened across the patient's chin. One end of the tubing is sealed; the open end is connected with the air stream of the air pump. The perforations are placed over the chin and directed toward the nose. The closed end of the tube is fitted with a metal ring. A strip of hernia tape extends

from this ring around the back of the neck and is tied loosely to the opposite arm of the tubing. The patient is then draped for operation in the usual manner. The force of the air current may be regulated from the machine.

BENJAMIN FRIEDMAN.

Orbit, Eyeball and Accessory Sinuses

INVOLVEMENT OF THE ORBIT IN CHRONIC INFLAMMATION OF THE FRONTAL SINUS. M. C. BENFORD and H. BRUNNER, Am. J. Ophth. 30: 297 (March) 1947.

Benford and Brunner conclude that acute orbital infections of rhinogenic origin are commoner than orbital tumors of rhinogenic origin and that these tumors arise from infections of the ethmoid cells or the frontal sinus. They may be caused by granulating periostitis, herniation of the sinal mucosa or orbital invasion by nasal polypi.

W. S. REESE.

SOME OBSERVATIONS ON THE SYMPTOMATOLOGY AND DIAGNOSIS OF CASES OF PROPTOSIS. H. BEY, Brit. J. Ophth. 31: 155 (March) 1947.

The causes of proptosis may be classified as those of extraorbital or intraorbital origin and disease of the bony wall of the orbital cavity. Notwithstanding various degrees of proptosis and deviations of the eyeball, diplopia is rarely complained of and only exceptionally elicited. Careful histories should be taken and systematic local and general examinations routinely made to aid in the differential diagnosis.

Distention of the orbit may result from either intraorbital or extraorbital conditions. Intraorbital, or primary, distention is consistent with the presence of an intraorbital lesion. It was the only evidence of intraorbital tumor in 16 of 21 cases of proptosis.

W. ZENTMAYER.

A CASE OF ORBITAL APEX SYNDROME IN COLLATERAL PANSINUSITIS. H. KJÆR, Acta ophth. 23: 357, 1945.

The symptoms characteristic of the fully developed syndrome may be classified as follows: (1) motor: complete external and internal ophthalmoplegia; (2) sensory: disturbances corresponding to distribution of the lacrimal, frontal and nasociliary nerves; (3) visual: disturbances resulting from optic neuritis and subsequent atrophy, and (4) exophthalmos.

The case of a man aged 59 with this symptom complex is described. Pansinusitis was regarded as the responsible etiologic factor.

O. P. PERKINS.

The Pupil

STUDIES OF THE CAUSES OF SENILE MIOSIS AND RIGIDITY OF THE PUPIL. S. LARSSON and G. ÖSTERLIND, Acta ophth. 21: 1, 1944.

The histologic examination of iris tissue removed at operation for cataract in 14 cases is described. The eyes were all studied clinically prior to operation, with particular reference to the ability of the pupil to dilate.

As a result of their observations, the authors believe that there is a relation between the power of pupillary dilatation and the degree of sphincteric degeneration. Moreover, there is excellent parallelism between the presence of postoperative and degenerative vascular changes and the power of the pupil to dilate. The observations are interpreted as showing that the background of senile miosis and rigidity of the pupil is primarily sclerosis of the vessels of the iris, with subsequent degeneration of the musculature and hyaline change in the stroma of the iris.

O. P. PERKINS.

Physiology

NEW WAYS OF STUDYING INTRAOCULAR PRESSURE. A. DASHEVSKY, Vestnik oftal. **24**: 18, 1946.

This is an extremely interesting article, but difficult to abstract. In 1939 Dashevsky worked out a new elastotonometric method for the study of intraocular tension. The elastotonometer has a prism which presses on the cornea (similar to the Fick-Livshitz tonometer); on the base of the prism are made special circles, so that when the prism is pressed on the cornea deformity of the cornea is produced in three diameters. The tonometer records in grams the amount of pressure on the cornea. A table shows the three increasing tonometric pressures in millimeters of mercury. These pressures are transferred to a nomogram, which is calculated according to Friedenwald's theory of the logarithmic relationship of pressure and replacement of volume of fluid.

This new elastotonometer makes it possible to study the basic components of ophthalmotonus—the true intraocular pressure and the coefficient of rigidity (of Friedenwald). Dashevsky named the latter component the coefficient of reactivity because the eye responds to pressure by adequate reaction—increase of pressure. The study also led to new problems in the field of disturbance of the hydrodynamic equilibrium of the eye. The retinal edema appears as a manifestation of disturbance of the permeability of the choroidal wall.

O. SITCHEVSKA.

Refraction and Accommodation

ACCOMMODATIVE ASTIGMATISM. J. M. O'BRIEN and R. E. BANNON, Am. J. Ophth. **30**: 289 (March) 1947.

O'Brien and Bannon remark the difference in the amount or axis of astigmatism during accommodation. From an examination of 50 eyes with three technics, they found a consistent increase of from 8 to 10 per cent for near vision. They believe that this should be noted in the higher degrees of astigmatism.

W. S. REESE.

Retina and Optic Nerve

ADHESIVE EPISCLERAL REACTION IN THE OPERATIVE TREATMENT OF RETINAL DETACHMENT. L. WEEKERS, Brit. J. Ophth. **30**: 715 (Dec.) 1946.

The various procedures used in the operative treatment of retinal detachment aim at promoting adhesive choroiditis at the retinal tear.

On the basis of experimental and clinical observations, especially of operative results, the author expresses the belief that, in addition to adhesive choroiditis, it is necessary to create an adhesive episcleral reaction, the importance of which is paramount, for it affords particularly firm attachments which militate against relapses. An adhesive episcleral reaction takes place irrespective of the method of perforation, provided the perforation is complete. The episcleral tissue proliferates actively, progresses in depth and becomes firmly attached to the retina. The steps in the operation for retinal detachment incorporating puncture for production of adhesive episcleral reaction are described. The nonperforating diathermic electrode is applied to the sclera. The point of the diathermy needle is placed against the sclera. Slight pressure applied as soon as the current is on causes instantaneous perforation. The needle is then swiftly withdrawn without turning off the current. A galvanocautery wire is heated to a dark red color. The sclera is then lightly touched at the required spot, and the cautery wire is immediately withdrawn. Thus a small cup is formed. After an interval of a few seconds the same maneuver is repeated and the cup deepened. With two or three such applications the perforation is completed and the fluid escapes. The reasons for the several steps in the operation are given. The operation is concluded by the evacuation of the subretinal fluid.

W. ZENTMAYER.

SUBJECTIVE LIGHTNING STREAKS. R. F. MOORE, Brit. J. Ophth. **31**: 46 (Jan.) 1947

Moore returns to a reconsideration of this subject, first discussed in the *British Journal of Ophthalmology* in October 1935, as he is now able to add the personal experiences with the symptoms of three ophthalmic surgeons and he has also become a subject of the "streaks." The streaks are very bright, of momentary duration, and travel from above down. They are curved and do not exhibit the zigzag feature of lightning. While they almost always occur at the outer side of the eyes, they certainly do occur in other positions; they persist much longer in the temporal field than elsewhere. The streaks do not occur with the eyes at rest; whether movements of the head alone will elicit them he is not sure, but believes it likely that they will. Probably in most cases the condition becomes bilateral in time. No limit can be put to the period for which they may occur. There is a close relation between the occurrence of these streaks and the simultaneous development of opacities in the vitreous. Moore believes that Verhoeff's explanation of the immediate cause of the streaks is probably the correct one; he attributes them to shrinking and partial separation of the vitreous, which then impinges on the retina on movement. Moore still believes that the streaks have no sinister meaning, either at the time or, what is more important, eventually.

W. ZENTMAYER.

OCULAR LESIONS FOLLOWING TRITOLUENE POISONING. G. AJELLO, Ann. oftal. e clin. ocul. **72**: 17, 1945.

In the case reported a woman aged 23 employed in the preparation of tritoluene compounds complained of gradual loss of vision in the

left eye. Ophthalmoscopic examination of the left eye showed the presence of round and flame-shaped hemorrhages along the course of the retinal vessels, papillitis, a macular star and hemorrhages in the vitreous.

G. BIETTI.

Tumors

ACHROMIC MELANOMA OF THE CHOROID. J. P. PICENA and F. P. ALLENDE, An. Arg. de oftal. **7**: 39 (April-June) 1946.

The authors believe this case to be of interest because of the rarity of the achromic variety of melanoma and because the histogenesis of this tumor has long been wrongly interpreted. A woman aged 80 stated that vision in the right eye had been decreasing for several months and that the eye was now blind. The cornea was slightly opalescent; the anterior chamber was shallow; the ocular tension measured 33 mm. of mercury (Schiøtz) and the media was cloudy, making ophthalmoscopic examination difficult. A tumor the size of a filbert could be seen at the posterior pole of the fundus; it was grayish white and elevated the retina. The eye was enucleated because of secondary glaucoma. Histologic examination revealed a malignant melanoma of achromic type.

M. E. ALVARO.

Uvea

A CASE OF BILATERAL GENUINE IRIS-ATROPHY. I. CYUKRÁSZ, Brit. J. Ophth. **31**: 176 (March) 1947.

A woman aged 24, with no history other than that of intolerable headaches and poor vision of the right eye, had always been blind in the left eye. Vision in the right eye was 1/3 with a —8 D. sphere. Intraocular pressure in each eye was 56 mm. of mercury. The pupil of the right eye was eccentric, directed toward 3 o'clock and roughly triangular, reaching almost to the root of the iris. The pigment border below and above on the nasal side was intact. The iris tissue was atrophic, the frill being present only above and below. Temporarily, a defect from 8 to 11 o'clock reached the angle of the anterior chamber; between the coloboma and the pupil a strip of iris tissue 5 mm. in width had no frill or pigment border. In the left eye the cornea was slightly stippled. The pupil was continued as a coloboma above. Two holes could be seen in the region of the iris root, one at 11 and the other from 1 to 4 o'clock. The iris tissue was atrophic. The greater defect was divided into two parts by a stout bundle of trabeculae. There was slight iridodonesis. The optic disk was atrophic and showed a deep, glaucomatous cup.

The author concluded that the regressive function of the iris is influenced by an inhibitory factor. One can imagine that if, in these embryonic mechanics, in the activity of action and reaction, the faintest disturbance arises, the balance is overturned and there develops what Riger called dysgenesis mesodermalis.

W. ZENTMAYER.

IRIDOCYCLITIS AS A LATE RESULT OF LEPTOSPIROSIS POMONA. O. GSELL, K. REHSTEINER and F. VERREY, Ophthalmologica 112: 320 (Dec.) 1946.

A case is reported of unilateral iridocyclitis with nodules of the iris occurring in a patient who had previously recovered from an infection with Leptospira pomona (swineherd's meningitis). After excluding the other usual causes of iridocyclitis, the authors state the belief that the iritis in this case was due to Leptospira pomona. They found a high titer of agglutinins to leptospirosis pomona in the aqueous humor, together with a large increase in leukocytes. In the second case, in which the patient had also recovered from leptospirosis, the iridocyclitis came on seven months after the meningitis. In the second case, also, there were lymphocytes in the aqueous and mononuclear cells, but no agglutinin could be demonstrated.

F. H. ADLER.

Vision

PHENOMENA OF FLUCTUATION, EXTINCTION AND COMPLETION IN VISUAL PERCEPTION. M. B. BENDER and H. L. TEUBER, Arch. Neurol. & Psychiat. 55: 627 (June) 1946.

In this paper a detailed investigation of the phenomena of fluctuation, extinction and completion is presented. The study was made on a series of patients with damage to the brain, and some of the determining factors, particularly the time relationships involved, were analyzed. Observations made on after-images and in tachistoscopic and perimetric examinations were compared for each patient. Various supplementary methods were applied whenever it seemed indicated.

By fluctuation the authors mean that the visual image in the affected region may fluctuate in distinctness at a varying rate or may disappear and reappear at a certain rate. By extinction they mean that during fixation at a given point the image disappears completely in any part of the field of vision after a certain period. Between extinction and fluctuation of the visual image a continuum of intermediate states may be found. These gradations may be subsumed under the term "obscuration" (dimming) of the image. In certain cases extinction can be demonstrated only under special conditions. Objects exposed to impaired parts of the field may become invisible on simultaneous exhibition of another stimulus in a less impaired or in an intact part. Completion of images should be understood as follows: Images involving both impaired and comparatively unimpaired regions of a field of vision are "completed" under certain conditions. This takes place in spite of the fact that the image is invisible if presented to the impaired region alone. Again, several gradations are possible. Sometimes only partial continuation of figures into the defective region is encountered.

This work demonstrates that the usual perimetric measurements give an adequate picture of loss of impairment of anatomic structure but do not unequivocally define how much a patient sees. The methods employed determine, in addition, spatial and temporal factors in perceptual organization. For example, the field of vision is different as judged by the appearance of after-images or by measuring with the tachistoscope (which presents targets at varying speeds) or by com-

pletion of simple objects, such as squares, oblongs or circles, presented to the visual field, than as judged by the results of the usual perimetric and tangent screen tests. The findings indicate that the visual projection area seems to operate in an integral fashion, circumscribed lesions not necessarily producing functional loss of an "all or none" character, and that one must think beyond simple point for point correspondence in considering what the patient actually sees.

S. R. IRVINE.

DEPTH PERCEPTION IN INDIRECT VISION. J. GAUS, Ophthalmologica **112**: 1 (Oct.-Nov.) 1946.

Using the method of diverging threads described by Monje for testing acuity of stereoscopic vision (*Ztschr. f. Sinnesphysiol.* **69**: 73, 1940), the author determined the values for depth perception in indirect vision His results are as follows:

1. Stereoscopic vision is present in the paracentral parts of the retina.
2. The angle of rotation necessary to achieve depth perception is in inverse proportion to the distance in depth of the middle thread.
3. The upper paracentral parts of the retina possess a depth perception more acute than that of the lower parts.
4. The acuity of depth perception of the paracentral parts of the retina is analogous to the curves of angular visual acuity.

F. H. ADLER.

AN INTRODUCTION TO THE CLINICAL STUDY OF FUSION FREQUENCY. R. WEEKERS and F. ROUSSEL, Ophthalmologica **112**: 305 (Dec.) 1946.

An apparatus is described for measuring the fusion frequency with intermittent light stimuli. The fixation point of the patient remains fixed, while the test objects can be thrown on any part of the retina desired. In this fashion, the authors hope to compare the results of the measurements of the critical fusion frequency with changes in the visual fields. The subject is completely dark adapted, and the pupil is dilated to get rid of the variations in the fusion frequency with size of pupil. Fusion frequency is measured at fixation and in the area 30 degrees from center. The diameter of the test object varies from 3 to 7 degrees. The authors find that the normal fusion frequency varies from 36 to 46 impulses per second. Values lower than 36 impulses per second must be looked on as pathologic.

F. H. ADLER.

Book Reviews

A Treatise on Gonioscopy. By Manuel Uribe Troncoso, M.D. Price, $10. Pp. 306, with 117 illustrations, 35 in color. Philadelphia: F. A. Davis Company, 1947.

This first book on gonioscopy written in the English language is a welcome addition to ophthalmic literature, especially since its author is the "father" of modern gonioscopy.

The subject is completely covered, beginning with chapters on the comparative anatomy of the angle of the anterior chamber in mammalia and the microscopic anatomy of the angle in man. The latter contains much new material on the relations of the insertion of the root of the iris to the shape and depth of the chamber. The basic chapters include also one on the comparative physiology of the angle. Ida Mann has contributed a valuable chapter on the development of the angle of the anterior chamber in the human eye.

After the basic chapters, Troncoso discusses the history and development of gonioscopy and the various instruments and technics, both past and present. The chapter on the normal angle introduces some important ideas in nomenclature. The use of the term "trabeculum" is defended, since it is a term designating the tissue as an organ, to distinguish it from its component trabeculae. This is entirely justifiable, in spite of the fact that the manuscript editors of the ARCHIVES have in the past insisted on using the term "trabecula" to maintain the proper Latin ending of the singular of "trabeculae." Troncoso prefers the term "rudimentary pectinate ligament fibers" to the older "iris processes." However, he continues to use the term "line of Schwalbe," which is a confusing term in the reviewer's opinion.

Troncoso discusses, in sequence, the senile conditions, congenital anomalies, injuries, inflammatory conditions and tumors of the angle. He then discusses gonioscopy in the study of the various types of glaucoma.

The final chapter, entitled "Miscellaneous Diseases," discusses gonioscopy in cases of hypoplasia of the iris and cornea, mesodermal dysgenesis of the iris, essential atrophy of the iris and the Kayser-Fleischer ring in Wilson's disease (hepatolenticular degeneration). Much of this material is new.

Several small misinterpretations have been noted, none of which detracts from the value of this fine work. On page 240 the statement is found that "capsular exfoliation has been found in a great number of cases diagnosed as simple glaucoma, the incidence varying from 70 per cent to as high as 93 per cent." My own calculations from the literature varied from 6 to 89 per cent. Actually, the incidence is nearer the smaller figure than the larger one.

On page 239 there is a reference to 11 cases of glaucoma capsularis. This figure should be 37. Again, on page 269, the author states, "According to Sugar, a visible separation of the lips of the wound can

be detected in 79 per cent of the successful and 62 per cent of the unsuccessful operations." This is a misinterpretation, since the separation of the wound lips cannot be detected gonioscopically. The figures represent the number of clinically successful and unsuccessful operations.

On page 231 Troncoso mentions the occurrence of congestive glaucoma in myopic eyes with deep anterior chamber and wide angle as an argument against the shallowness of the angle being the primary cause of acute glaucoma, as "Sugar and Kronfeld have lately been inclined to believe." The difference in opinion here is based on the use of the term "acute glaucoma." The two authors mentioned use the term "acute glaucoma" only in reference to narrow angle eyes, whether congestion is or is not present. They do not deny the occurrence of acute congestive episodes in simple glaucoma or secondary glaucoma of varying causes but consider them as different in mechanism.

Unlike Busacca (ARCH. OPHTH. 35: 710 [June] 1946), who stated that gonioscopy is of little value in differential diagnosis of glaucoma, Troncoso sees gonioscopy in the study of glaucoma for what it is worth. He, like most other American gonioscopists, does not expect too much from gonioscopy in the diagnosis of primary glaucoma. However, in differentiating primary and secondary glaucoma gonioscopy is invaluable. It helps to differentiate between congestive attacks of acute primary glaucoma and congestive episodes of secondary glaucoma. In cases of aphakia it is the only means of determining whether the glaucoma is secondary to adhesions obstructing the angle or is a true simple glaucoma in an aphakic eye. Gonioscopy's value in diagnosis of postoperative glaucoma is exhaustively covered by Troncoso.

The illustrations in this volume are superb and are the most complete of any material on gonioscopy. The bibliography is fairly complete. The paper, printing and binding are of excellent quality. Dr. Troncoso deserves much credit for this addition to his numerous and important contributions. The book deserves a place in every ophthalmologist's library.

H. SAUL SUGAR.

Industrial Diseases of the Visual Organ. By Stephen de Grósz, M.D., Associate Professor, University Eye Clinic, No. 1, Budapest. Pp. 96, with 7 figures. Budapest, Hungary: University Press, 1947.

This monograph (in the Hungarian language) is concerned with industrial ophthalmology, that is, with diseases due to long-standing exposure to various hazards; accidental injuries are not included.

Chapter 1 is concerned with external diseases, caused by the direct action of dust, fumes and vapors (exposure to various mineral substances, plants or animal material). Dimethyl sulfate poisoning, of which an extensive description was previously given by the author, is characterized by stippling of the cornea, due to acid fission products. The problem of goggles is stressed, with demonstration of the new American models.

In chapter 2, the deleterious action of radiant energy in industry is discussed, especially photophthalmia of arc welders and cinema employees. The studies of Duke-Elder, F. Law, Birch-Hirschfeld and others are mentioned. The technical aspects of the glass industry

are described for a better understanding of glassblowers' cataract, which is decreasing constantly in frequency. Electric cataract, though an industrial accident rather than a disease, is mentioned, and the barometric and thermal changes which produce pathologic changes in the eye are considered.

Chapter 3 deals with intoxication. In addition to lead poisoning, the role of carbon disulfide (in rayon factories) and the carbohydrogens, such as methyl bromide, trichloroethylene, benzene, 2,4,6-trinitrotoluene (TNT) and trinitrophenol, are reviewed. The peripheral portion of the optic pathway is generally involved (toxic amblyopia) with central scotoma. Probably the part affected is not the nerve, but the ganglion cells of the retina at the origin of the papillomacular bundle. It is emphasized that malnutrition is an essential factor in, if not the cause of, the toxic amblyopia. Possibly a lack of thiamine results in lowering cellular respiration. This deficiency may be brought about by the toxic products themselves or a poor utilization of thiamine which they produce or by a primary hypovitaminosis associated with undernourishment. Whereas formerly lead poisoning was of primary importance, today intoxication due to organic solvents has the lead.

The pathogenic role of carbon monoxide in producing anisocoria in drivers has been stressed by French authors. Blindness due to methyl alcohol was observed regularly after warfare (nonindustrial cases); the disturbance in regeneration of rhodopsin manifests itself as dysaptation. Like other substances (quinine), methyl alcohol sensitizes the ganglion cells to ultraviolet radiation.

The chapter on infectious diseases comprises epidemic keratitis (virus), tularemia and two "modern" diseases among agricultural workers—a benign form of leptospirosis (*méningite des jeunes porchers*), causing an influenza-like ailment accompanied with iritis, during which agglutinins may be recovered from the aqueous, and brucellosis (undulant fever), which frequently produces uveitis.

The chapter on miner's nystagmus is based on British experience. The toxic theory is rejected, and preponderance of the role of faulty illumination is stressed (Verhage's adaptometric studies). Near work, problems in illumination engineering, compensation and a program for visual improvement in industrial plants (Kuhn) are the other subjects considered. The classification of Minton and the "orthorater" (United States Army) are discussed.

Bibliographic references are given at the end of each chapter. This monograph, written for ophthalmologists, should be a valuable aid in detecting and preventing industrial lesions of the eye, and should replace the section on industrial hygiene in textbooks, which is generally inadequate, or may be completely lacking.

The preface was written by Dr. Vikol, secretary of state, and Prof. G. Horay, director of the University Eye Hospital, no. 1. Previous studies of the author's on physical therapy and vitaminology are often mentioned.

S. DE GRÓSZ, M.D.

The Oculorotary Muscles. By Richard G. Scobee, M.D., Price, $8. Pp. 359, with 113 figures. St. Louis: C. V. Mosby Company, 1947.

The author starts this book with two handicaps. He has coined a new word, "oculorotary." This would not have been too serious if he had confined it to the title, as its meaning is fairly obvious; but he has persisted in using it with annoying frequency. To me it is an awkward word, and one for which I can find little need. He then introduces a set of abbreviations for the various oculorotary motor muscles and some of their actions. Abbreviations have a definite place in records, but they should be used sparingly in a book, and then only when their acceptance is nearly universal, which is not the case here. They definitely detract from the readability of this book.

This work is a complete treatise on ocular motility and its disturbances except that all discussion of surgical technic has been omitted. The author has used many quotations, some several pages long, from past and contemporary writers. Much of this is valuable material, not readily available to the student; yet this manner of writing makes for difficult, disconnected reading. Scobeé is an ardent disciple of Chavasse; yet he would have greatly increased the value of the book for the novice (for whom he professes to have written it) if he had paraphrased Chavasse's ideas in his own words. No book of this sort can bring only the original ideas of the author; he must borrow from others, and it is entirely proper that he should give credit. It makes, however, for much better continuity of thought and smoother reading if the borrowed material is expressed in the author's own words.

In many ways, Scobee has presented a fresh approach to the subject, which should be stimulating to those familiar with the older texts. I like his short, concise chapters, with frequent subheadings. He has brought in most of the newer ideas, although he may have followed Chavasse too closely to please some readers. This adherence to the teachings of Chavasse is exemplified in the surgical treatment of a paretic muscle or in which he advocates as the first procedure always doing a recession of the antagonist. This may be attractive on a theoretic basis, but practically it will lead to trouble.

The followers of Duane will be disappointed to find so little of his teaching perpetuated in this volume. That Scobee does not believe it important or worth while to measure with prisms the deviation in the six cardinal directions will be considered a serious omission by many.

I find it difficult to evaluate this book. Many parts of it are extremely elementary, with fundamental principles hammered in by constant repetitions in italics. On the other hand, many other parts are distinctly detailed and complex, such as the discussions of physiology, the innervational causes of heterophoria and testing conditions in hyperphoria—complexities which may well leave the novice confused and discouraged. Some of the definitions are overly long and involved for students, such as those for orthophoria and angle kappa. Scobee's style, to me, is provocative. He challenges many of one's favorite ideas. His positiveness and definite rules for so many things will appeal to the student, though they may raise a skeptical eyebrow among the more experienced. Particularly open to question are the close correlations that he finds between certain symptoms and the various heterophorias; I question, also, the practical value of his carefully detailed discussion of cyclophoria.

Though most readers will find a number of things with which they cannot agree, or accept simply on the author's statement, there is a great deal of valuable material in this book. It is not the clear, simple exposition of the subject that is so sorely needed, but there is much of interest and worthy of careful study.

MAYNARD WHEELER.

The Blind Preschool Child. Edited by Berthold Lowenfeld, Ph.D. Price, $2. Pp. 148. New York: American Foundation for the Blind, Inc., 1947.

The book is a compilation of papers by doctors, educators and social workers read before a National Conference on the Blind Preschool Child, convened under the auspices of the American Foundation for the Blind, Inc.

The topics discussed were classified under three main heads, viz., social work aspects, educational aspects and medical aspects.

The authors stressed the importance of focusing attention not on the handicap itself but on the tensions and factors that may disrupt the normal family life. Particular attention should be paid to the parental attitudes toward the blind child. The attitude of the parents may be one of oversympathy or a feeling of rejection. Considerable discussion is devoted to the psychologic pattern which is set up in the early formative years of the blind child. The psychologic pattern is greatly influenced by mother love, home influences and environment. It has been found that children in institutions, who in the first years of their lives have been deprived of warm and human mothering care and who have been denied the normal relationships of family life, develop infantile personalities. They lack the capacity to think and talk well and do not acquire the confidence required to meet the experiences of social communication and human relationships.

The proper education and training of social workers who have to deal with the preschool blind child were stressed. Individual case work with parents and methods for guidance of mothers in making adjustments to the situation were outlined, as were also training programs and projects for bringing the mothers and children and trained social workers together for conferences and discussion of the various problems that confront the mother and child. Meetings at which opportunities were afforded mothers to observe the technics of trained attendants and teachers in handling and instructing the blind child were described.

Placing of the preschool blind in nursery schools and kindergartens with seeing children was advocated in order that the blind child, by association with seeing children, may acquire a feeling of security and independence.

The medical subjects discussed were "Early Diagnosis of Visual Defects," by Dr. Brittain F. Payne; "Hereditary Aspects of Blindness," by Dr. Robert R. Chace; "Retrolental Fibroplasia," by Dr. Merrill J. King, and "Development and Guidance of the Blind Infant," by Dr. Arnold Gesell.

The book will be particularly valuable to social workers who are interested in aiding blind children. Ophthalmologists will find it well worth reading, as it will give them a better insight into the problems that confront the parents of blind children and the difficulties that attend the education and training of the blind child of preschool age.

THOMAS H. JOHNSON.

Non-hypophysäre chiasmasyndrome. M. Gil Espinosa. Bibliotheca Ophthalmologica, supplement to *Ophthalmologica*, No. 32. Pp. 60, with 15 illustrations. Basel and New York: S. Karger, 1946.

After a short introduction on the anatomy and physiology of the optic chiasm, the chiasmal syndrome is described and two groups of symptoms are distinguished: (1) main symptoms, which are the result of a direct lesion of the chiasm (changes in the visual field, reduction of vision and changes in the eyeground); (2) secondary symptoms, which sometimes accompany the first group, though they are not so frequent and are not the direct result of the chiasmal lesion but depend on the kind, localization and extent of the process which has caused the chiasmal syndrome (hypophysial and hypothalamic symptoms; roentgen findings; encephaloventriculoarteriographic appearances). Surgically, the lesions which produce a chiasmal syndrome may be divided into two groups: (1) lesions which are caused by direct injury to the chiasm and (2) indirect involvement of the chiasm by hydrocephalus of the third ventricle or by indirect pressure from the adjoining parts of the brain.

Eight cases are fully recorded which illustrate the more important nonhypophysial lesions, such as craniopharyngioma, craniopharyngioma and hydrocephalus, tumor of the third ventricle and infundibulum, aneurysm, solitary tubercle and meningioma.

The author states that one can now distinguish between direct and indirect chiasmal compression, as well as suprasellar and intrasellar processes with the aid of the procedures to be indicated. The perimetric examination of the field must be made with small test objects (1 to 2 mm. diameter) in order to detect the presence of early chiasmal processes. The early changes in the visual fields, their intensity, outline and chronologic development are of the greatest importance for diagnosis. In addition to the clinical symptoms, stereoscopic roentgenologic studies and encephaloventriculoarteriographic examinations give valuable information. In short, according to the author, it is now almost always possible to determine the localization and the extent of the pathologic process in the chiasmal region, and thereby information of the greatest importance for prognosis and treatment is obtained.

This book is an excellent and instructive monograph on a subject of importance to the neurologist, as well as to the ophthalmologist.

ARNOLD KNAPP.